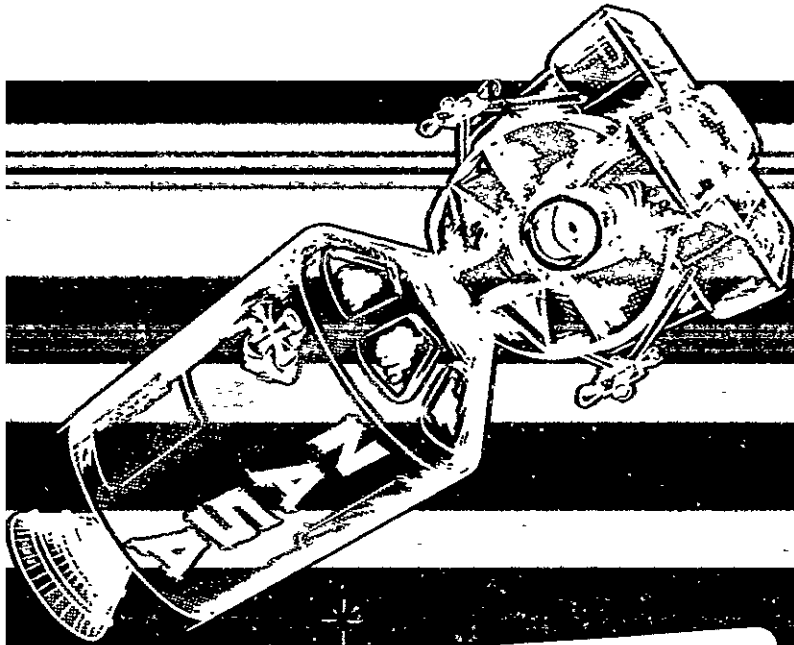


# MANNED SPACE FLIGHT NETWORK



AUGMENTATION STUDY  
FOR THE

APOLLO  
EXTENSION  
SYSTEM

PART I

SEPTEMBER 1, 1965

TRACKING AND DATA SYSTEMS DIRECTORATE

GODDARD SPACE FLIGHT CENTER  
GREENBELT, MARYLAND

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## FOREWORD

This document, Part I of a two-volume report prepared by the Tracking and Data Systems Directorate, Goddard Space Flight Center, presents a condensed version of the results of a study to determine the capability of NASA's tracking and data acquisition facilities in support of the proposed Apollo Extension System (AES) program. Conclusions are presented regarding the augmentation of facilities and operations of the Manned Space Flight Network (MSFN) as well as for the augmentation of the NASA Communications Network (NASCOM) deemed necessary to adequately cover the AES missions.

Part II, the second volume of the report on the Manned Space Flight Network Augmentation Study for the Apollo Extension System, will provide detailed information on the procedures of this investigation and the pertinent analyses which have been used to draw the conclusions given in Part I of the report. The purpose of Part II of this document is to provide the mission planner with the necessary detailed information pertaining to the ground network.

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## I. INTRODUCTION

At the present time the NASA space flight programs are supported by the Manned Space Flight Network (MSFN), the Deep Space Network (DSN), and the Satellite Tracking and Data Acquisition Network (STADAN). Since the Apollo Extension System (AES) Program by definition is an extension of the Manned Space Flight Program, primary consideration for the network support is directed to the Manned Space Flight Network. The MSFN has been subject to considerable updating and augmentation to meet the support requirements for the current Gemini missions. Additional augmentation has been approved, and will be incorporated for the coverage of the Apollo earth-orbital and lunar missions. This study was undertaken in cooperation with the Office of Manned Space Flight (OMSF), the Office of Tracking and Data Acquisition (OTDA), and the Goddard Space Flight Center (GSFC).

Goddard Space Flight Center is responsible for the planning, analysis, implementation, and operation of NASA's world wide tracking networks, namely the Manned Space Flight Network and the Satellite Tracking and Data Acquisition Network. Likewise, GSFC is responsible for the NASA Communication Network (NASCOM) which provides teletype, voice and data links between the stations and the mission control centers.

It is the purpose of this report to give a condensed description of the networks mentioned above and to present a preliminary plan for the augmentation and operation of these networks in support of the AES missions.

Four characteristic missions representative of the AES program have been chosen for this study:\*

1. Low inclination earth orbital missions (28.5° inclination)
2. Polar orbital missions (96.5°, 90°, and 81.5° inclination)
3. Synchronous orbital missions (0° and 28.5° inclination)
4. Lunar missions

For the above missions the limitations imposed on the AES program by the present network configuration are discussed. The modifications required to

---

\*Although a 50.3° earth orbital mission is not anticipated at this time, we have investigated this problem.

eliminate these limitations by augmentation of the equipment at existing stations, ships and aircraft, and the associated communications network are then developed. In the absence of specific information on certain aspects of mission requirements, assumptions had to be made which helped to formulate the ground rules (Chapter III). It should be pointed out that these ground rules are to be considered as guidelines only and not as stringent criteria. .

## II. AES MISSION DESCRIPTION

Twenty-four AES missions are presently planned (ref. 1 and 2), nine lunar and fifteen earth orbital. The orbit inclination, altitude, duration and mission flight number are shown in Table 1 which was derived from schedule AE 65-1 as given in ref. 1 and 2. Although the AE 65-1 flight schedule has been recently superceded, the work in this report is based on AE 65-1, which is a typical flight schedule. Hence, the necessary augmentations presented in this report would not be affected appreciably by subsequent schedule changes.

Mission experiments are divided into four groups of twelve major categories as follows:

### SPACE TECHNOLOGY/OPERATIONS

- Extravehicular Engineering Activities Experiments
- Advanced Technology & Supporting Research Experiments
- Advanced Mission Spacecraft Subsystems Experiments

### SPACE SCIENCE/APPLICATIONS

- Astronomy/Astrophysics Experiments
- Bioscience Experiments
- Physical Science Experiments
- Biomedicine/Behavior Experiments
- Atmospheric Science and Technology Experiments
- Communications & Navigation/Traffic Control Experiments

### REMOTE SURFACE SENSING

- Earth Sciences and Resources Experiments
- Lunar Orbital Survey Experiments

### LUNAR SURFACE EXPLORATION

- Lunar Surface Experiment & Supporting Equipment

Several simultaneous missions (rendezvous) are scheduled (ref. 1) in the latter part of the AES program. Hence the necessary augmentations allow for support of this type of mission with limited data transfer.

Table 1  
AES Missions\*

A. EARTH ORBITAL MISSIONS			
Inclination Orbit (°)	Altitude (nm)	Duration (Days)	Mission (Flight Number)
96.5	200	14	507
96.5	200	45	518
81.5	200	14	513
50.3	200	14	215
0	19,350	14	509
0	19,350	45	516
0	19,350	45	521
28.5	200	14	209
28.5	200	30	211
28.5	200	45	218
28.5	200	45	219
28.5	200	45	221
28.5	200	45	523
28.5	200	45	229
28.5	200	45	230
B. LUNAR ORBITAL MISSIONS			
10	80	35	511
10	80	14	514
0	80	21	515
90	80	35	517
90	80	14	519
90	80	21	520
90	80	35	522
90	80	14	524
90	80	21	525

\*Based on AE65-I Flight Schedule

### III. GROUND RULES

The ground rules stated in this chapter are those formulated jointly by the Office of Manned Space Flight, the Office of Tracking and Data Acquisition, and the Goddard Space Flight Center to assure a common understanding for the development of this report.

It is the purpose of the ground rules to furnish basic guidance (not stringent requirements) needed for the analysis of mission coverage by the ground tracking and communication networks. It should be noted that while these ground rules are preliminary in nature, they will permit all participants to initiate their work within a common, uniform set of basic guidelines which affect the augmentation of the NASA ground networks for the AES missions.

#### Ground Rule #

- 1      The AE 65-1 Flight Schedule given in ref. 2 shall be followed.
- 2      Periods with a peak density and most stringent requirements of the AE 65-1 Flight Schedule shall be used for determining the limitations of the existing networks and the minimum augmentation needed with respect to AES mission coverage.
- 3      In case of multiple assignment of launch vehicles to different missions, one of them being an AES mission (AE 65-1 Flight Schedule), the AES mission shall be considered for planning purposes of the present study.
- 4      For polar earth orbits, limits of 96.5 degrees and 81.5 degrees orbit inclination will be considered.
- 5      Re-entry from polar orbits will be from either the North or the South into either the Northern or Southern Pacific.
- 6      Low inclination earth orbits are considered to be orbits with 28.5 degrees inclination.
- 7      No plane change will be made for the synchronous orbit during re-entry.
- 8      Only nominal missions will be considered; no contingency or emergency mode will be analyzed.

Ground  
Rule #

- 9 No orbit decay due to drag is considered. However, the perturbations in the spacecraft trajectory for the earth orbital missions caused by the perturbations in the earth's gravitational potential at least through the second harmonic are considered.
- 10 Minimum tracking requirements:
- 10A Continuous tracking plus one minute is required from launch to insertion into an initial orbit,
  - 10B For station contact considerations, a contact time of at least four minutes and an elevation angle of at least five degrees are assumed,
  - 10C At least one contact with a duration of four minutes or greater per day after orbit verification is required,
  - 10D One four minute pre-retro contact within 90 minutes before retro is required,
  - 10E One four minute post retro-contact within two to five minutes after retro fire is required,
  - 10F For the AES lunar missions the tracking requirements are the same as those for Apollo.
- 11 Minimum telemetry requirements:
- The time between two successive four minute contacts shall not exceed two hours.
- 12 For the purpose of the study, a five-degree RF horizon is assumed for all frequencies.
- 13 C-Band capability will be maintained.
- 14 A high gain antenna is available for use on the Apollo spacecraft for all missions after staging of the S IV-B.
- 15 The MSFN for Apollo mission coverage is defined by the Apollo/Saturn V-PSR (ref. 3).

Ground  
Rule #

- 16        Ships will be used only for coverage of insertion, injection, and re-entry.
- 17        Apollo final design spacecraft hardware (S-Band, C-Band and VHF) will be used at least through 1969 for the AES missions.
- 18        The VHF ground equipment in the MSFN will be available to the AES program through 1970 to accommodate those missions which require data capacity in excess of what the present Unified S-Band can provide and to allow time for the development of new spacecraft hardware.

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#### IV. SUMMARY OF NECESSARY AUGMENTATIONS FOR AES GROUND NETWORK SUPPORT

As a result of the detailed analysis to be presented in Part II of the GSFC report on "Manned Space Flight Network Augmentation Study for the Apollo Extension System" and given in a condensed fashion in subsequent chapters of this report, four major augmentations were found to be necessary, namely the augmentation of the present networks, the NASA Communications Network augmentation, the network operations augmentation, and conversion of four single USBS stations to dual stations.

##### A. Augmentation of Present Networks

The augmented network for AES support is shown in Figure 1. The AES Network includes all present MSFN stations plus Fairbanks, Alaska subject to the following augmentations.

##### 1. Equipment Augmentation at Fairbanks, Alaska

To provide the increased capability necessary for the coverage of polar or near polar AES missions, additional equipment and appropriate building facilities are needed at Fairbanks, Alaska.

The augmentation at this already existing STADAN station will be comprised of the following items:

- a. Unified S-Band System including a new 30' antenna
- b. Processing Equipment
- c. VHF Equipment
- d. Building Facilities

##### 2. Equipment Augmentation at Existing MSFN Stations

Preliminary estimates of the total information bandwidths generated while the AES experiments are in progress in the spacecraft, indicate that additional telemetry links will be required to handle the high information rate during earth survey and mapping. In addition, television transmissions of near commercial quality (4 megacycle bandwidth) have been

# APOLLO EXTENSION SYSTEM NETWORK

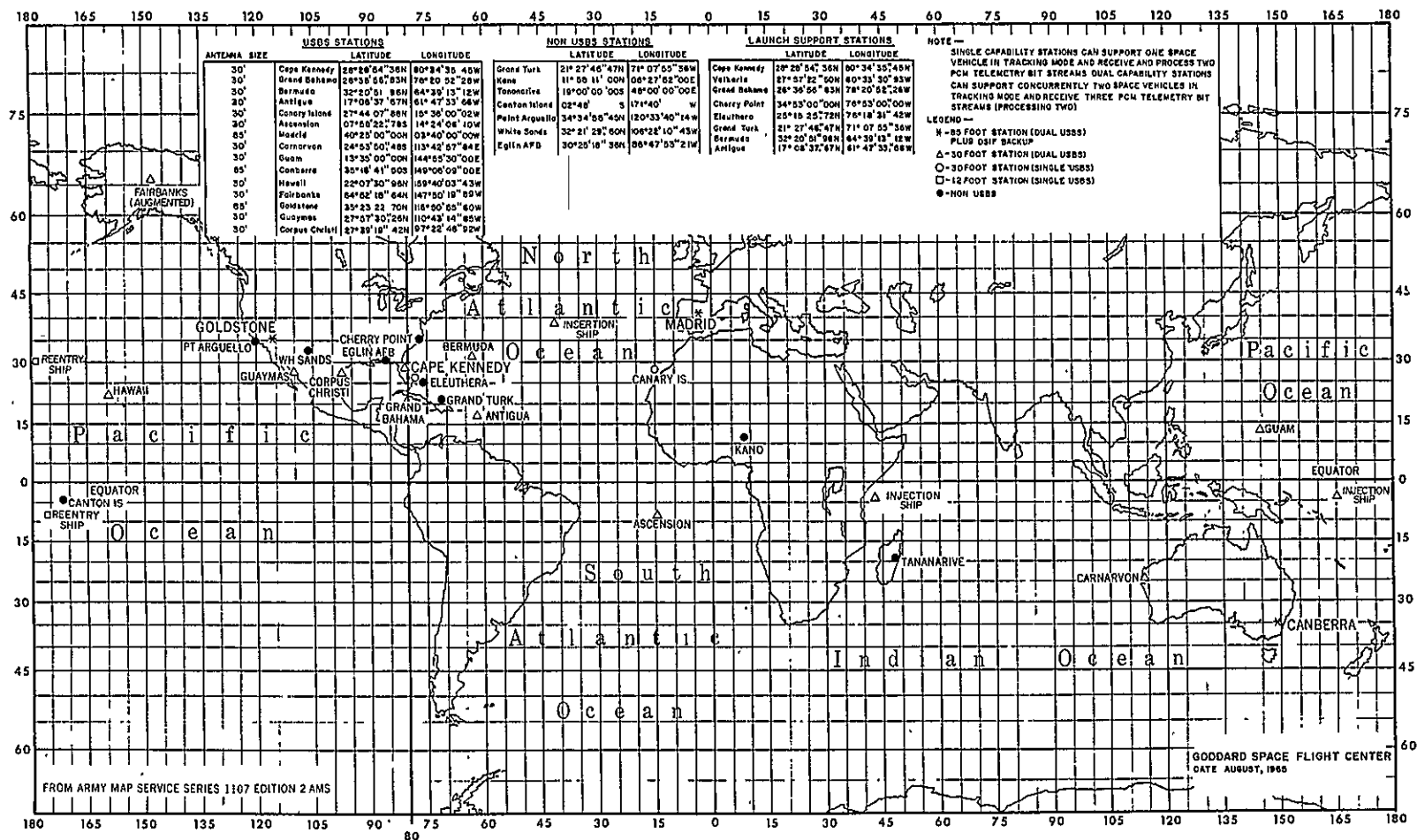


Figure 1—Apollo Extension System Network

specified in preliminary analyses of spacecraft experiments. It has been assumed that telemetry data and television will be dumped from the AES spacecraft for real time processing and transmission.

The spacecraft to ground telemetry links required to handle AES experimental data transmissions will require additional processing equipment at existing Unified S-Band stations. It must be noted however, that this additional equipment is a preliminary estimate and can only be substantiated when the AES experiments are more firmly defined. The basis of information on AES experimental data was obtained from ref. 4 and 5.

Instrumentation augmentation will be required at 13 USBS stations (Table 2) for adequate fulfillment of the AES experimental data transmission and handling requirements. These requirements include decommutation, processing, and recording of data. A list of augmentation items per station is given in Table 3.

Table 2  
USBS Stations Requiring Data Processing  
Instrumentation Augmentation

Cape Kennedy	Guam
Bermuda	Canberra
Antigua	Hawaii
Canary Islands	Goldstone
Ascension	Guaymas
Madrid	Corpus Christi
Carnarvon	

Table 3  
Augmentation Items Per USBS Station

PCM Systems
Data Processor
W/B Recorders
W/B TV Recorders and Converters
Spares
Building Modifications

## NASCOM Network Augmentation

### 1. Necessary Augmentation

The study has indicated that data communication facilities between the tracking stations and the mission control center should be improved.

Since all available ground circuits are already in service in most of the critical areas, and since the cost of these facilities is quite high, it is necessary that automatic circuit switching equipment be installed at the USB ground station to make more efficient use of existing trunk lines and cables. (See Chapter VI for details.) The store-and-forward data switching equipment will provide for circuit and message switching at the stations which will enable optimum use of the existing and available ground lines.

### 2. Communication Satellite Option

An optional proposal for the augmentation of the NASCOM Network which could be much more desirable and less costly to operate than the store-and-forward data switcher involves the installation of a communications satellite system. Two multiple access synchronous satellites positioned at the international dateline ( $180^{\circ}$ ) and at  $15^{\circ}$  West Longitude would provide simultaneous communications of approximately 96 KC information bandwidth between the MCC-H and all of the overseas USB ground stations of the MSFN and at Fairbanks, Alaska. An alternate mode of operation would permit transmission of TV from the 85' antenna sites at Canberra and Madrid during the lunar phases of the AES missions. The communication satellite system would involve satellite ground terminals co-located with the USB ground stations at Carnarvon, Canberra, Guam, Hawaii, Fairbanks, Madrid, Canary Island, Ascension, Bermuda, and the USB Insertion and Injection ships. A communication satellite system would provide wideband, real-time communication channels for data transfer to MCC-H with high reliability and low error rate. This is particularly true for communications with the Apollo ships, thus making them more useful primarily from the viewpoint of real-time operations.

## NOTE

A VHF transponder has already been proposed for utilization in order to make it possible for aircraft to communicate with the U.S. via a communication satellite. Using an Apollo VHF transponder on the AES spacecraft and an appropriate antenna system would permit voice relay through the communications satellite to the MCC-H. Almost full time voice contact with the astronauts in the spacecraft would be possible and would not be dependent upon ground station acquisition periods. Such an arrangement could eliminate the need for retaining and staffing supplemental ground stations that are used primarily for voice relay only.

### C. Network Operations Augmentation

Analysis has been made of the operational impact of the AES program, as scheduled by AE 65-1, on the MSFN. There are 24 AES launches, and the duration of the AES missions extends from 14 days to 45 days, with emphasis on the latter. Thus, there will be manned spacecraft in orbit about 50% of the total time for the duration of the AES program.

In addition, the AES mission profiles and mission coverage (see Chapter VI) have been analyzed.

Based on the above analyses, the following network operations augmentation was found to be necessary:

1. Fourteen of the USB equipped AES ground stations (excluding Grand Bahama) plus the network operations control center at GSFC need to be operated on a continuous basis; that is, 24 hours per day, 7 days per week.
2. Stations required to operate on a continuous basis (168 hours per week) should be manned for a four shift operation (three 40 hour week shifts and one 48 hour week shift). Experience has shown this to be the most economical and efficient method.
3. Increasing the manpower for a "four shift" operation will involve only the operations personnel which represent about 64% of the total personnel at a given ground station.
4. Additional personnel will be needed at GSFC in the Tracking and Data Systems Directorate.

#### D. Conversion of Four Single USBS Stations to Dual USBS Stations

The study of the data transmission requirements during the AES schedule has indicated that a deficiency exists in the data transfer equipment at some of the MSFN stations. To make more efficient use of the transmitting equipment in the spacecraft, and to increase the overall network capability it is necessary that existing single USBS receiving systems be changed to dual USBS receiving systems at Bermuda, Antigua, Texas, and Guaymas.

The conversion of these receiving systems will increase the available data transfer time by 10 to 15 percent. These four stations were chosen because of their location and good communication links, which make them well suited for real-time dump of prime data "over" the U.S. The necessary equipment augmentation and associated operational costs are relatively small since the USB electronic system is the only part of the network affected by the augmentation.

Furthermore, the resulting uniformity in transmitting procedures will result in less complex transmitting operating procedures in the spacecraft, and also alleviate the mission planning problem.

## V. SUMMARY OF THE AES NETWORK CAPABILITIES

Following is a summary of the capabilities of the network augmented to support the AES missions. The purpose of this chapter is to present to the reader in a condensed form those charts, tables, and numbers which are important to understand the necessary augmentations.

### A. The AES Network

Figure 2 shows all stations which are intended to be used in support of the AES missions. This figure shows station location, antenna size, DSIF backup, and type of USBS equipment (dual or single). In addition, the stations are categorized and distinguished as USBS, Non USBS, or Launch Support.

The augmented network for AES support is the MSFN as planned for Apollo with the following augmentation:

1. Addition of a USBS station at an existing STADAN site at Fairbanks, Alaska.
2. Additional decommutation, processing and recording equipment at all USBS stations except Grand Bahama.
3. Conversion of 4 single USBS stations to dual USBS (Bermuda, Antigua, Texas, Guaymas).
4. Augmentation of the NASCOM Network with store-and-forward switching equipment at all the USBS stations except Grand Bahama and Cape Kennedy.
5. Augmentation of Network Operations to 24 hours continuous operation at 14 USBS stations (Grand Bahama excluded), and the GSFC Network Operations Control Center.

# 

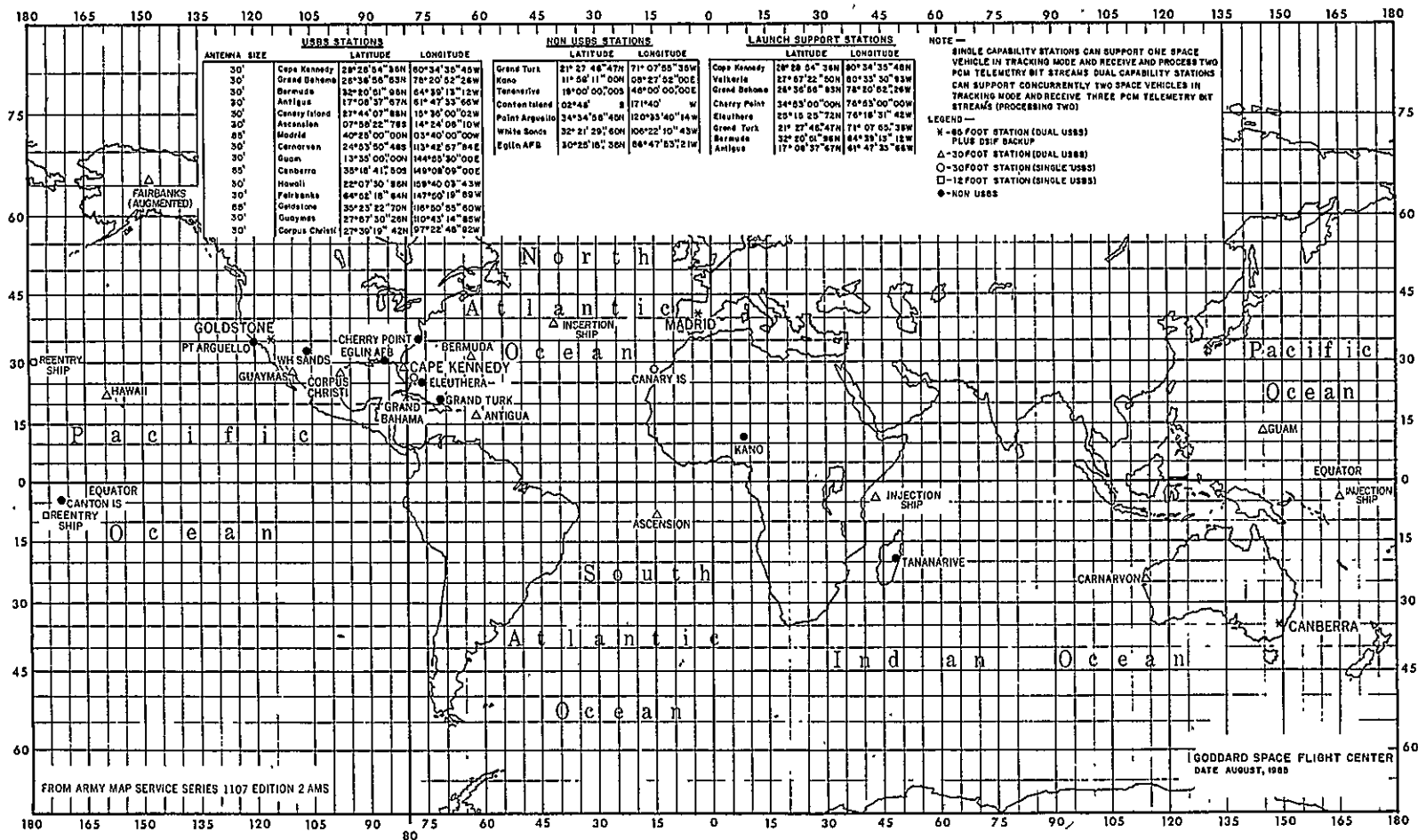


Figure 2-Apollo Extension System Network

## B. Network Capability

### 1. Contact Times and Data Transfer Times

Figure 3 depicts the first few orbits of a low inclination earth orbital mission together with the visibility limits for each of the stations. This example considers a 200 nm circular orbit assuming a 5 degree horizon limit for tracking and communications. A detailed time sequence for the first few orbits is given in Figure 4 showing station contact intervals as well as the time intervals between contacts. Graphs of this kind have been used in arriving at most of the conclusions presented in this report. Figure 5 shows a typical orbit map for earth polar missions including coverage limits of all the AES network stations, and Figure 6 presents the detail time sequence of the station contacts for the first few orbits.

Table 4 shows those intervals of time which are in excess of 120 minutes between successive 4 minute contacts and actually violate ground rule 11. On the other hand, as can be seen, only a few orbits are involved. Hence there is no sufficient reason to build an additional station.

Table 5 shows the average net data transfer times for the AES Network. It should be noted that the data transfer times are those which can be utilized for the experiments since spacecraft housekeeping and spacecraft acquisition times have already been subtracted.

### 2. Communication Capability

Table 6 shows the data handling and processing capability of all the USBS stations of the network. Also shown here is the data transmission capability of the augmented NASCOM network and the utilization improvement factor. It should also be pointed out that the total data handling capacity is shown here including operational data and that not all of this capability is available to the AES experiments since some must be reserved for operations. It should be noted that the utilization improvement factor shown in Table 6 reflects only the increased efficiency obtained by configuring the voice/data circuits planned for the Apollo USB ground stations in a circuit switching arrangement rather than the presently configured point-to-point arrangement. Shown in Table 7 is an example of the computation of the utilization improvement factor due to circuit switching. The improvement in traffic handling capability is even greater than shown in Table 6, because the message switching feature of the proposed store-and-forward equipment will give approximately another order of magnitude improvement. Furthermore, the reliability of the NASCOM network is increased, because in the event of a circuit fault or overflow, the switching equipment immediately switches the output or the overflow to another circuit.

# AES NETWORK COVERAGE FOR LOW INCLINATION EARTH ORBITAL MISSIONS

$i=28.5^\circ$ ,  $H=200$  nm,  $\epsilon \geq 5^\circ$ , ORBITS 1 through 8

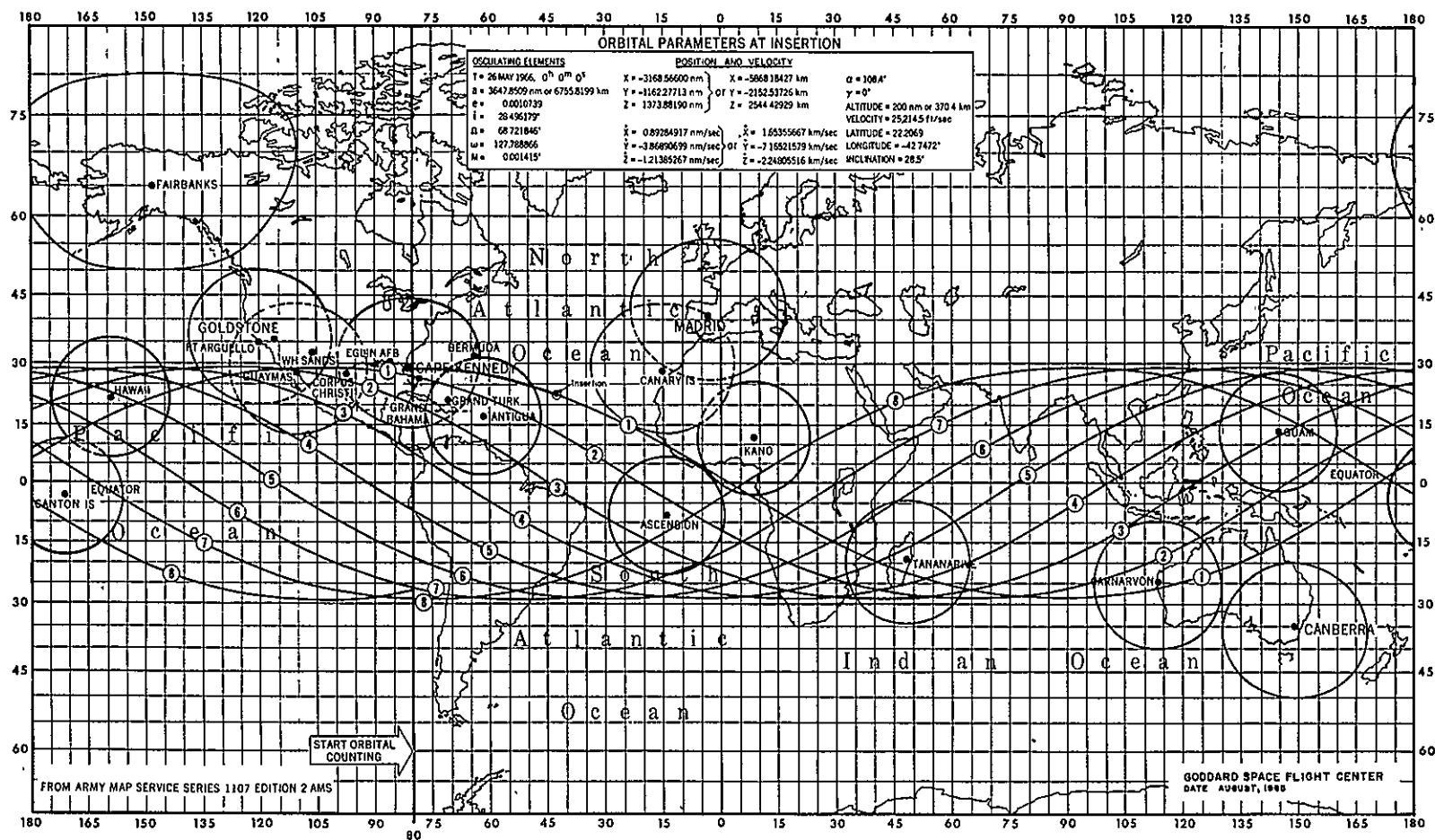




Figure 3—AES Network Coverage for Low Inclination Earth Orbital Missions:  $i = 28.5^\circ$ ,  $H = 200$  nm,  $\epsilon \geq 5^\circ$ , Orbits 1 through 8

# DETAILED TIME SEQUENCES FOR LOW INCLINATION EARTH ORBITAL AES MISSIONS

$i=28.5^\circ$ ,  $H=200\text{nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 1 to 8

## ORBITAL PARAMETERS AT INSERTION

OSCILLATING ELEMENTS		POSITION AND VELOCITY	
$T = 26 \text{ MAY } 1966, 0^h 0^m 0^s$	$X = -3168.56600 \text{ nm}$	$X = -5868.18427 \text{ km}$	$\alpha = 108.4^\circ$
$a = 3647.8509 \text{ nm or } 6755.8199 \text{ km}$	$Y = -1162.27713 \text{ nm}$	$Y = -2152.53726 \text{ km}$	$\gamma = 0^\circ$
$e = 0.0010739$	$Z = 1373.88190 \text{ nm}$	$Z = 2544.42929 \text{ km}$	ALTITUDE = 200 nm or 370.4 km
$i = 28.496179^\circ$			VELOCITY = 25,214.5 ft/sec
$\Omega = 68.721846^\circ$	$\dot{X} = 0.89284917 \text{ nm/sec}$	$\dot{X} = 1.65355667 \text{ km/sec}$	LATITUDE = 22.2069°
$\omega = 127.788866^\circ$	$\dot{Y} = -3.86890699 \text{ nm/sec}$	$\dot{Y} = -7.16521579 \text{ km/sec}$	LONGITUDE = -42.7472°
$M = 0.001415^\circ$	$\dot{Z} = -1.21385267 \text{ nm/sec}$	$\dot{Z} = -2.24805516 \text{ km/sec}$	INCLINATION = 28.5°

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

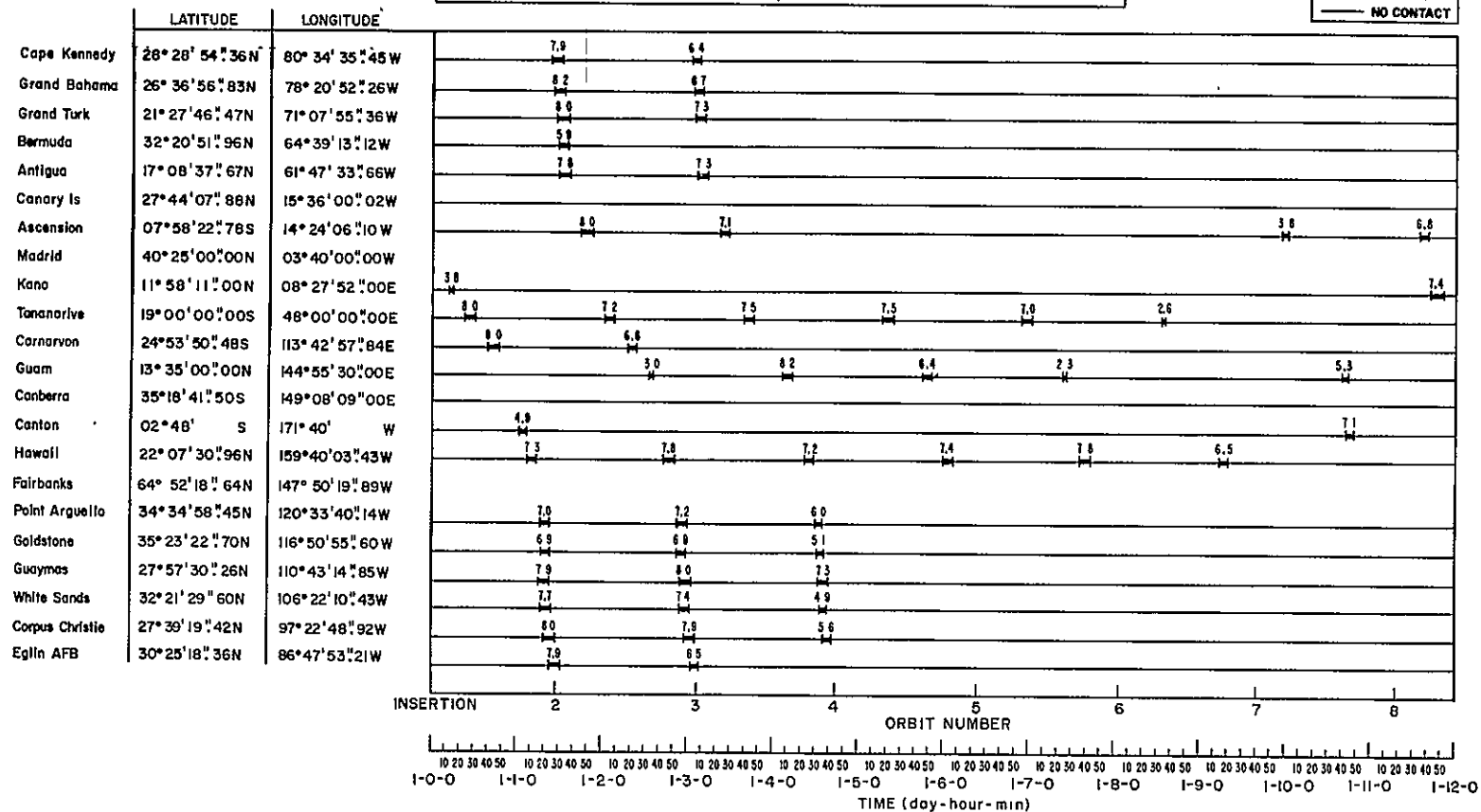


Figure 4—Detailed Time Sequences for Low Inclination Earth Orbital AES Missions:  
 $i = 28.5^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 through 8

# AES NETWORK COVERAGE FOR EARTH POLAR MISSIONS

$i=96.5^\circ$ ,  $H=200$  nm,  $\epsilon \geq 5^\circ$ , ORBITS 1 through 18

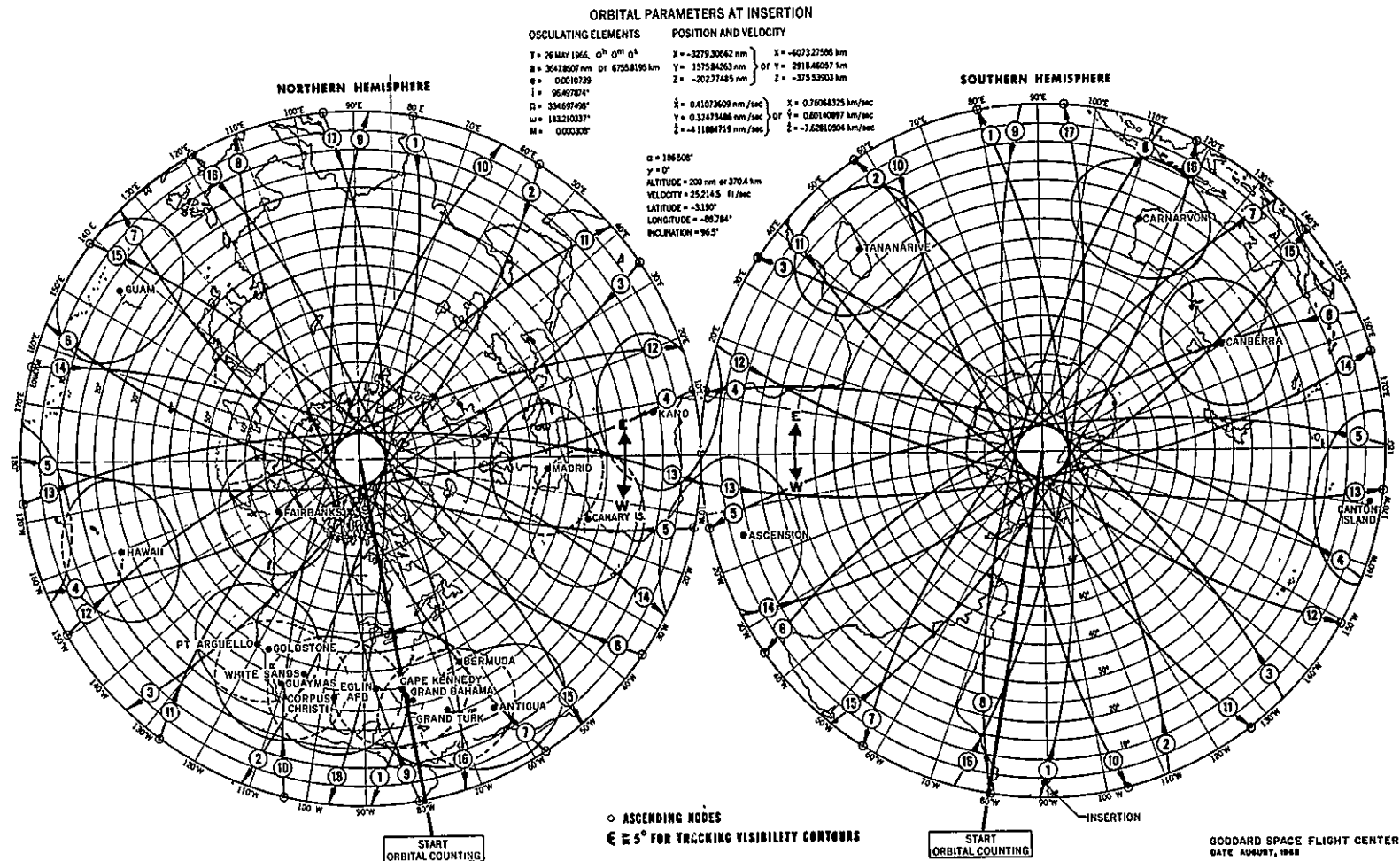


Figure 5--AES Network Coverage for Earth Polar Missions:  $i = 96.5^\circ$ ,  $H = 200$  nm,  $\epsilon \geq 5^\circ$ , Orbits 1 through 18

# DETAILED TIME SEQUENCES FOR EARTH POLAR AES MISSIONS

$i=96.5^\circ, H=200 \text{ nm}, \epsilon \geq 5^\circ$ , ORBITS 1 to 9

## ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS	POSITION AND VELOCITY		
T = 26 MAY 1966 0 <sup>h</sup> 0 <sup>m</sup> 0 <sup>s</sup>	X = -3279 50642 nm	X = -6073.27688 km	$\omega = 186.508^\circ$
a = 3647 8507 nm or 6755 8195 km	Y = 1575 84263 nm	Y = 2916 46057 km	$\gamma = 0^\circ$
e = 0.0010739	Z = -202 77495 nm	Z = -375 53903 km	ALTITUDE = 200 nm or 370 4 km
i = 96 497874°			VELOCITY = 25,214 6 ft/sec
$\Omega = 334 697498^\circ$	X = 0 41073609 nm/sec	X = 0 78066325 km/sec	LATITUDE = -3190°
$\omega = 183 210337^\circ$	Y = 0 32473498 nm/sec	Y = 0 60140897 km/sec	LONGITUDE = -88.784°
M = 0 000308°	Z = -4 11864719 nm/sec	Z = -7 6280904 km/sec	INCLINATION = 96 5°

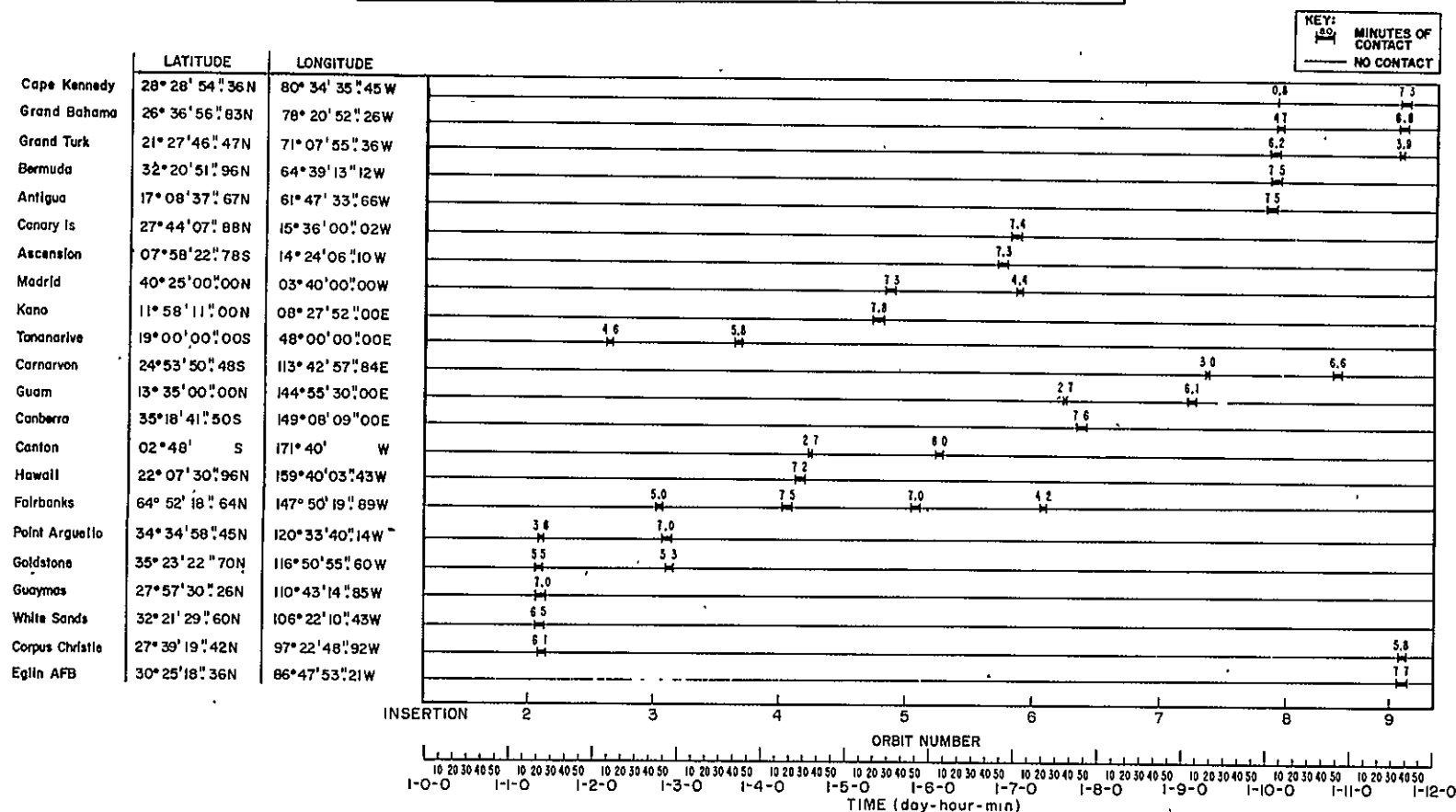


Figure 6—Detailed Time Sequences for Earth Polar AES Missions:  $i = 96.5^\circ$ ,  
 $H = 200 \text{ nm}, \epsilon \geq 5^\circ$ , Orbits 1 through 9

Table 4  
Apollo Extension System  
(Earth Orbital Missions)

Time Intervals in Excess of 120 Minutes Between  
Successive Contacts of Four or More Minutes Duration  
Using AES Network (USBS)

Orbits 1-48\*

Orbital Inclination	From D-H-M	To D-H-M	Total (min)
96.5°	None		
90.0°	None		
81.5°	1-4-31.6	1-6-47.2	136
	2-5-2.5	2-7-16.3	134
	4-4-30.3	4-6-44.2	134
28.5°	2-12-56.1	2-15-24.5	148

\* - Time Begins at Insertion

D - Days

H - Hours

M - Minutes

Table 5  
Average AES Net Data Transfer Times  
(min/day)

	Orbital Inclination				
	28.5°	50.3°	81.5°	90°	96.5°
Total Net Experimental Data* Transfer Time,** AES Network USBS Stations	667	535	411	364	359
Total Net Data Transfer Time VHF 1 Link at USBS Stations	381	318	248	219	216

\*Experimental Data Over and Above Housekeeping Data

\*\*Available Data Transfer Times After Acquisition

**Table 6**  
**AES Ground Station Data Handling and Transmission Capability**

STATIONS	*USB DOWNLINK RECEIVER/ DEMOM	PCM DEMOD	DATA PROCESSING	WIDE-BAND DATA AND TV TAPE RECORDING	USB UPLINK	**GROUND DATA TRANSMISSION	GROUND COMMUNICATIONS CIRCUIT SWITCHING <sup>1</sup>	GROUND COMMUNICATIONS CIRCUIT SWITCHING <sup>2</sup>	NO. OF 4-KC CHANNELS <sup>3</sup>	NO. OF 48-KC CHANNELS <sup>3</sup>
							NO. OF CIRCUITS/ DATA BIT RATE/CH	UTILIZATION IMPROVEMENT FACTOR <sup>2</sup>		
ALASKA (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 3 = 3 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 3 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(1) CHAN AT 40.8 KB (1) TV	6 V/D AT 2.4 KB	22	12	1
CAPE KENNEDY (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 3 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(1) CHAN AT 40.8 KB (1) TV	1 CHAN AT 40.8 KB	0	-	-
GRAND BAHAMA (S) 3 DOWNLINK CARRIERS	200 KB/LINK x 2 = 400 KB	1 MEG B/SYSTEM x 3 = 3 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 3 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(1) CHAN AT 40.8 KB	-	-	-	-
BERMUDA (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 7 = 7 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 6 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB	6 V/D AT 2.4 KB	22	12	1
ANTIGUA (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 5 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB	6 V/D AT 2.4 KB	22	12	1
ATLANTIC SHIP (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 3 = 3 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	-	3 V/D AT 1.2 KB	10.5	12	1
CANARY ISLAND (S) 2 DOWNLINK CARRIERS	200 KB/LINK x 2 = 400 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 5 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(2) CHAN AT 2.4 KB	5 V/D AT 2.4 KB	18	12	1
ASCENSION (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 5 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(2) CHAN AT 2.4 KB	5 V/D AT 2.4 KB	18	12	1
MADRID (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 5 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB	6 V/D AT 2.4 KB	22	12	1
INDIAN OCEAN SHIP (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 3 = 3 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	-	3 V/D AT 1.2 KB	10.5	12	1
CARNARVON (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 5 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB	5 V/D AT 2.4 KB	18	12	1
CANBERRA (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 5 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB	5 V/D AT 2.4 KB	22	12	1
GUAM (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 5 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB	6 V/D AT 2.4 KB	22	12	1
PACIFIC SHIP (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 3 = 3 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	-	3 V/D AT 1.2 KB	10.5	12	1
HAWAII (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 6 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB	6 V/D AT 2.4 KB	22	12	1
GOLDSTONE (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 5 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB (1) TV	6 V/D AT 2.4 KB	22	-	-
GUAYMAS (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 6 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(2) CHAN AT 2.4 KB	5 V/D AT 2.4 KB	18	-	-
CORPUS CHRISTI (D) 3 DOWNLINK CARRIERS	200 KB/LINK x 3 = 600 KB	1 MEG B/SYSTEM x 6 = 6 MEG B	WORD STORAGE 32 K x 4 = 128 K TRANSFER RATE 1000 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 6 SYSTEMS 4.0 MC CHAN 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	(3) CHAN AT 2.4 KB	6 V/D AT 2.4 KB	22	-	-
ENTRY SHIP #1 (S) 2 DOWNLINK CARRIERS	200 KB/LINK x 2 = 400 KB	1 MEG B/SYSTEM x 3 = 3 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	-	1 V, 2 TTY	0	-	-
ENTRY SHIP #2 (S) 2 DOWNLINK CARRIERS	200 KB/LINK x 2 = 400 KB	1 MEG B/SYSTEM x 3 = 3 MEG B	WORD STORAGE 32 K x 2 = 64 K TRANSFER RATE 500 K (30-BIT WORDS) PER SECOND	1.5 MC/CHAN/ SYSTEM 2 SYSTEMS	200 BPS - INFO BIT RATE 1000 BPS - SUB BIT RATE	-	1 V, 2 TTY	0	-	-

\*LIMITING DATA TRANSFER SPACECRAFT/GROUND STATION

\*\*LIMITING REAL-TIME DATA TRANSFER TO MCC-H

NOTES 1. CIRCUIT SWITCHING - ALL OF THE VOICE/DATA CIRCUITS EXTENDING FROM THE APOLLO USB GROUND STATIONS WILL TERMINATE ON A STORE-AND-FORWARD TYPE DATA SWITCHER. THIS CONFIGURATION WILL PERMIT VOICE, BIOMEDICAL DATA, TELEMETRY DATA, COMMAND DATA, TRACKING DATA, AND OPERATIONAL/ADMINISTRATIVE MESSAGES TO BE TRANSMITTED OVER ANY OR ALL OF THE VOICE/DATA CIRCUITS AND THUS MAKE THE COMMUNICATIONS LINKS MORE EFFICIENT AND RELIABLE (SEE PARAGRAPH V.4.3).

2. UTILIZATION IMPROVEMENT FACTOR - THIS FACTOR IS DEVELOPED BY TAKING THE RATIO OF THE TRAFFIC HANDLING CAPACITY OF A GIVEN NUMBER OF CIRCUITS ARRANGED ON A CIRCUIT SWITCHING BASIS TO THE TRAFFIC HANDLING CAPACITY OF THE SAME NUMBER OF CIRCUITS ARRANGED ON A POINT-TO-POINT BASIS. BOTH ARRANGEMENTS MAINTAINING A CIRCUIT ACCESSIBILITY OF 99% (SEE TABLE V.4)

3. COMMUNICATIONS SATELLITE (OPTION) - THIS SYSTEM INVOLVES THE INSTALLATION OF COMMUNICATIONS SATELLITE GROUND TERMINALS COLLOCATED WITH THE OVERSEAS USB GROUND STATIONS OF THE MSFN TO PROVIDE FOR HIGHLY RELIABLE WIDE-BAND REAL-TIME DATA TRANSFER TO THE MCC-H

4. NUMBER OF 4-KC CHANNELS - CHANNELIZING EQUIPMENT WILL BE USED TO SUBDIVIDE ONE GROUP (48-KC BANDWIDTH) INTO AN EQUIVALENT OF 12 4-KC LINKS TO PROVIDE FOR NARROW-BAND VOICE, COMMAND, TRACKING, AND OPERATIONAL/ADMINISTRATIVE COMMUNICATION COORDINATION BETWEEN THE REMOTE GROUND STATIONS AND THE MCC-H. MUCH FLEXIBILITY IS POSSIBLE IN THE CONFIGURATION OF THE 48-KC GROUP.

5. NUMBER OF 48-KC CHANNELS - A SECOND 48-KC GROUP IS MADE AVAILABLE TO EACH OVERSEAS USB GROUND STATION TO PERMIT THE TRANSMISSION OF TELEMETRY AND BIOMEDICAL DATA TO MCC-H AT A TRANSMISSION SPEED OF 40.8 KBPS

Table 7  
Increased Communications Efficiency for AES  
Through Circuit Switching

Apollo (Present) 6 Trunks, Point to Point (99% CA*)	3.0 UM
AES - Recommended 6 Trunks, Circuit Switching (99% CA)	64.5 UM
Utilization Improvement Factor = 22	
No Change in Number of Leased Lines	
1 UM = 100 Seconds of Circuit Utilization	
99% CA = 0.01 Grade Service	

\*CA = Circuit Accessibility

Figure 7 diagrammatically depicts:

- a. the data rates (bits per sec) which can be transmitted from the spacecraft to a ground station, and from a ground station to the GSFC network operations control center, and thence to MCC-H at Houston
- b. the total amount of data (bits) which can be handled on a daily average for a polar mission.

For a polar mission, Table 8 gives the amount of both real time and near real time data (average bits per day) which can be transmitted from the ground stations to the GSFC network operation control center. The real time data will be transmitted during the times when contact is made with the spacecraft, and the near real time data will be transmitted during the times between contacts after the first acquisition.

An example of the communication capability between the ground stations and the network operation control center for low inclination earth-orbital AES missions is given in Table 9.

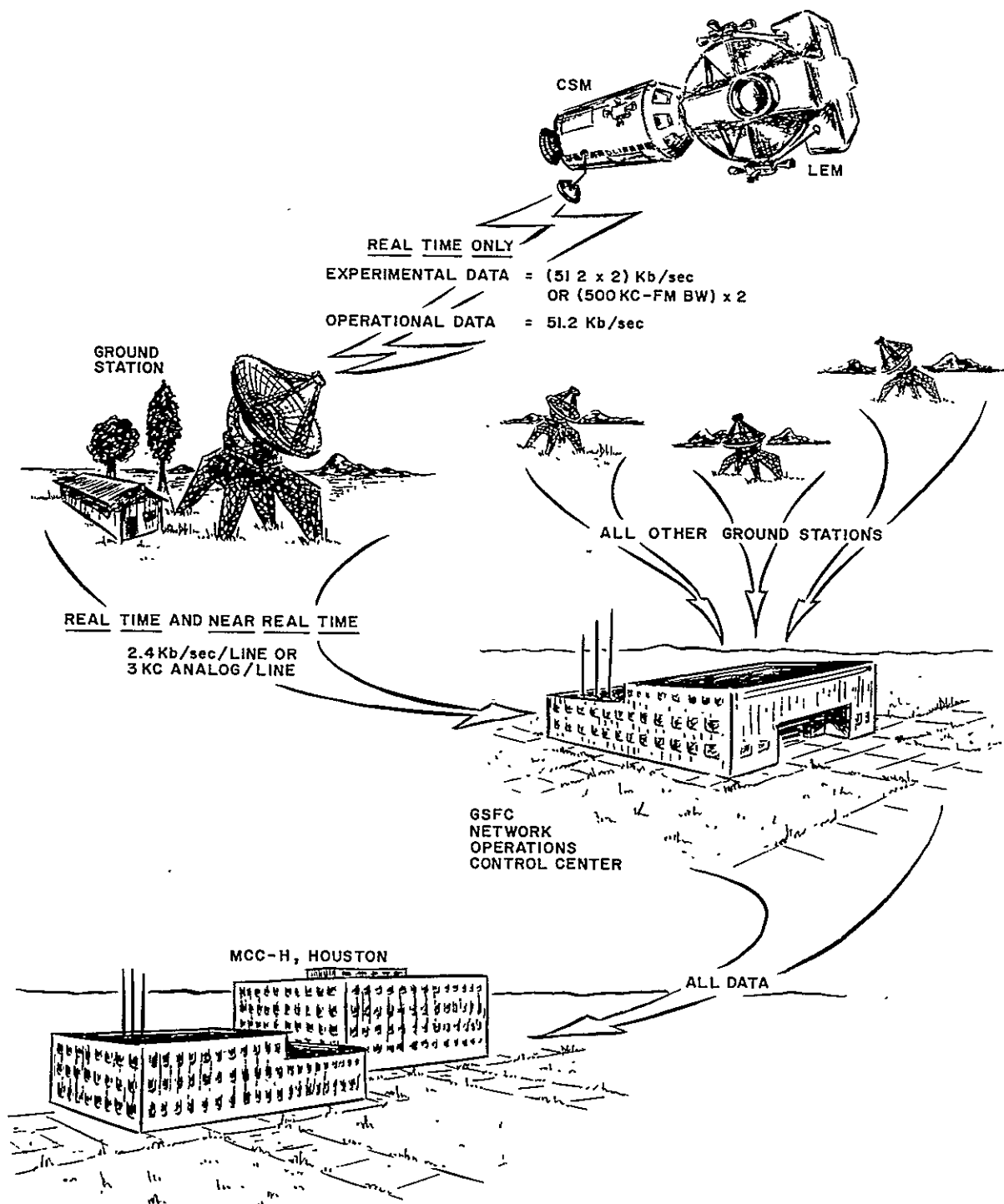


Figure 7—Data Capacity Routing Schematic

Table 8  
Summary of AES Communication Capability  
For Earth Polar Missions

CIRCUIT SEGMENT		SPACECRAFT TO GROUND	GROUND STATION TO MCC-H			
		TOTAL DATA***	REAL TIME		NEAR REAL TIME	
FROM	TO	(10 <sup>6</sup> BITS/DAY)	MIN/DAY	MAXIMUM CAPACITY** (10 <sup>6</sup> BITS/DAY)	MIN/DAY	MAXIMUM CAPACITY** (10 <sup>6</sup> BITS/DAY)
CAPE KENNEDY*	GODDARD SPACE FLIGHT CENTER	101	11	26.9	875	2140
GRAND BAHAMA* (SINGLE USBS)		74	12	29.4	876	2144
BERMUDA		129	14	8.1	895	515
ANTIGUA		774	8	4.6	792	456
CANARY ISLAND (SINGLE USBS)/MADRID		184	24	13.8	934	538
ASCENSION		110	12	5.2	926	400
CARNARVON/CANBERRA/ GUAM/HAWAII		461	50	28.8	924	532
FAIRBANKS		304	33	19.0	954	549
GOLDSTONE		138	15	8.6	975	562
GUAYMAS		129	14	6.1	962	416
CORPUS CHRISTI		120	13	7.5	982	566

\*CAPE KENNEDY AND GRAND BAHAMA HAVE ONE WIDE BAND TELEMETRY CHANNEL TO MCC-H OPERATING AT A TRANSMISSION RATE OF 40.8 KB/SEC.

\*\*THIS IS WITH THE STORE-AND-FORWARD DATA SWITCHING EQUIPMENT AND USING ONLY THE TELEMETRY CHANNELS.

\*\*\*THIS INCLUDES THREE 51.2 KB/SEC USBS CHANNELS (ONE FOR HOUSEKEEPING DATA AND TWO FOR EXPERIMENTAL DATA). THE REQUIRED ACQUISITION TIME HAS NOT BEEN SUBTRACTED FROM THESE FIGURES.

Table 9  
Summary of AES Communication Capability For  
— Low Inclination Earth Orbital Missions

CIRCUIT SEGMENT		SPACECRAFT TO GROUND	GROUND STATION TO MCC-H			
		TOTAL DATA***	REAL TIME		NEAR REAL TIME	
FROM	TO	(10 <sup>6</sup> BITS/DAY)	MIN/DAY	MAXIMUM CAPACITY** (10 <sup>6</sup> BITS/DAY)	MIN/DAY	MAXIMUM CAPACITY** (10 <sup>6</sup> BITS/DAY)
CAPE KENNEDY*	GODDARD SPACE FLIGHT CENTER	286	31	76.0	1117	2730
GRAND BAHAMA* (SINGLE USBS)		206	33	80.8	1116	2728
BERMUDA		212	23	13.2	1148	661
ANTIGUA		350	38	21.8	1088	628
CANARY ISLAND (SINGLE USBS)/MADRID		215	28	16.1	1184	681
ASCENSION		276	30	12.9	1114	480
CARNARVON/CANBERRA/ GUAM/HAWAII		1170	127	73.2	1009	581
FAIRBANKS		—	—	—	—	—
GOLDSTONE		203	22	12.6	1130	651
GUAYMAS		304	33	14.2	1117	482
CORPUS CHRISTI		313	34	19.5	1128	650

\*CAPE KENNEDY AND GRAND BAHAMA HAVE ONE WIDE BAND TELEMETRY CHANNEL TO MCC-H OPERATING AT A TRANSMISSION RATE OF 40.8 KB/SEC.

\*\*THIS IS WITH THE STORE-AND-FORWARD DATA SWITCHING EQUIPMENT AND USING ONLY THE TELEMETRY CHANNELS.

\*\*\*THIS INCLUDES THREE 51.2 KB/SEC USBS CHANNELS (ONE FOR HOUSEKEEPING DATA AND TWO FOR EXPERIMENTAL DATA). THE REQUIRED ACQUISITION TIME HAS NOT BEEN SUBTRACTED FROM THESE FIGURES.

## VI. SUPPORTING INFORMATION AND ANALYSES

The purpose of this chapter is to provide some of the information and analyses used in arriving at the necessary augmentations discussed in Chapter IV.

### A. Existing Network and Communication Capabilities

The GSFC-managed Manned Space Flight Network (MSFN) and Satellite Tracking Data Acquisition Network (STADAN) consist of ground stations located throughout the world. The MSFN stations are strategically located to support all of the NASA manned earth-orbital and lunar flights. The STADAN stations are used in support of earth-orbiting scientific satellites.

The NASA Communication Network (NASCOM) has been established to provide the necessary ground communications between the remote ground stations of the MSFN and STADAN networks and the project control centers at MCC-H and GSFC. They interconnect such facilities as NASA's foreign and domestic tracking, telemetry and command control sites, launch areas, test sites, and the mission control centers. The present NASCOM network consists of approximately 600,000 route miles of facilities including voice, teletype, and high speed data circuits.

#### 1. Tracking and Data Acquisition Networks

Figure 8 shows the worldwide coverage provided by the combined MSFN and STADAN networks for a typical orbital altitude of 200 nautical miles. The MSFN stations have been designed to provide coverage for low inclination (near equatorial) missions while the STADAN network provides coverage for low inclination as well as polar-orbiting spacecraft. Ships and aircraft are utilized during insertion, injection, and entry phases of missions.

##### a. Manned Space Flight Network (MSFN)

The primary purpose of the MSFN is to provide tracking, communications, telemetry and voice transmissions in real time between the spacecraft and the MCC-H in Houston, Texas. This capability is provided at MSFN stations with a Unified S-Band System, a VHF telemetry and voice system, a UHF command system and C-Band and S-Band tracking radars. The performance of a typical MSFN station is influenced by the strategic location of the station for mission coverage and the communication lines between the station and the mission control center. The availability of

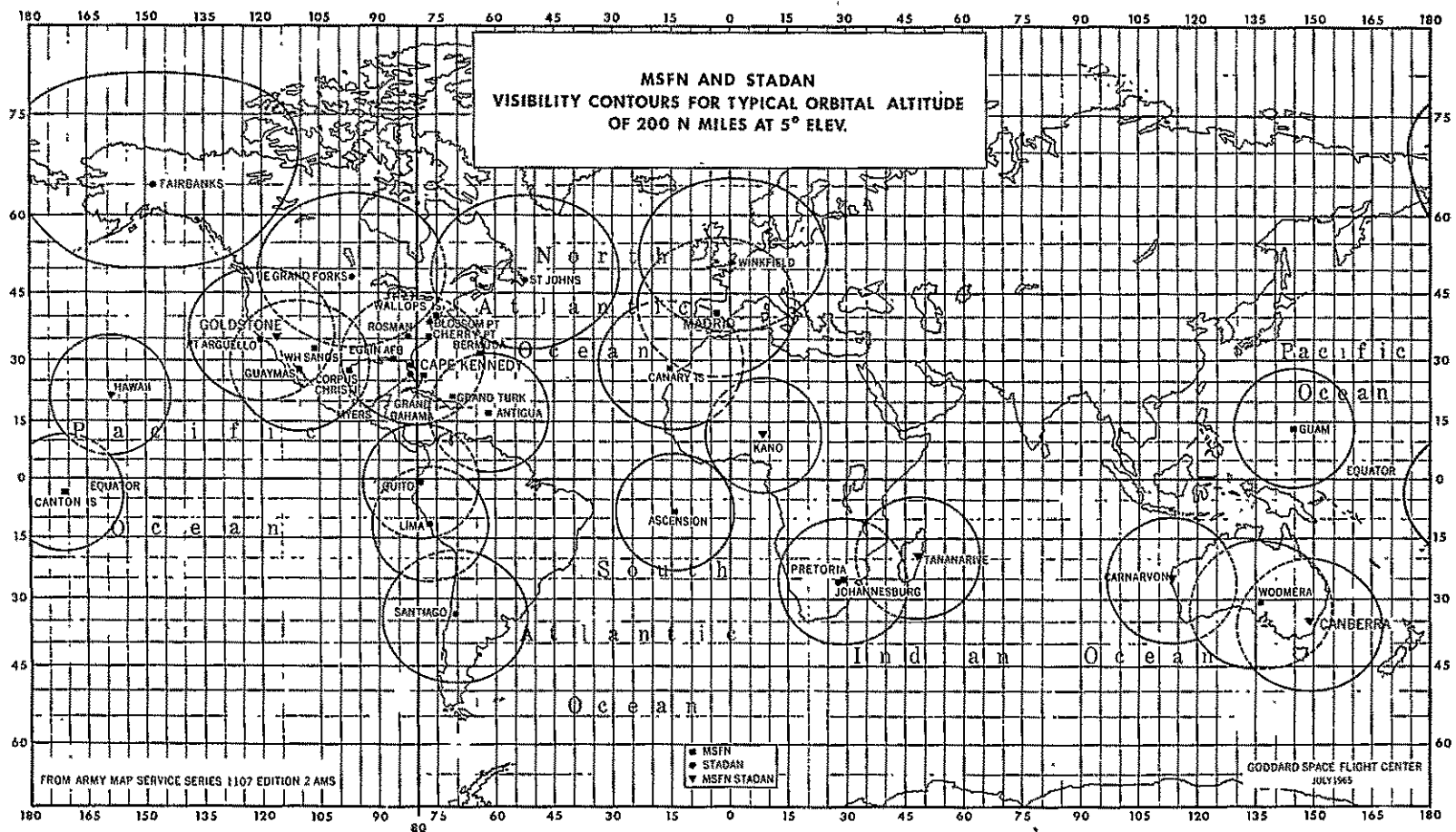


Figure 8—MSFN and STADAN Visibility Contours for Typical Orbital Altitude of 200 nm at 5° Elevation

real estate and technical personnel on foreign government land are also important factors for overall performance. The MSFN ground station systems are shown in Table 10. Data received from spacecraft can be processed, recorded, and transmitted to control centers. Seven stations (including three ships) can display telemetry and biomedical data on consoles.

The major system located at MSFN remote sites is the Unified S-Band System. The ground USBS has the inherent capability of receiving telemetry, voice, ranging and extracting Doppler on a single PM modulated carrier from the spacecraft. In addition, command data, ranging, and voice can be combined on a single PM carrier for transmission to the spacecraft. A single USBS station can receive three carriers and transmits one carrier while a dual USBS station can receive four carriers and transmit two carriers.

In addition to the USBS, 80% of the MSFN stations have VHF telemetry and voice capability. The VHF telemetry system supplements the USBS in monitoring spacecraft and astronaut performance. The transfer of commands from ground stations to spacecraft is accomplished by a USBS or UHF digital command system. C-Band and S-Band radars are available at approximately 95% of all MSFN stations.

A typical MSFN remote site systems block diagram is shown in Figure 9. Sites which do not have flight controllers will not have a memory character vector generator, a console computer, interface adapter, and flight control consoles.

The acquisition of spacecraft is accomplished by one of three methods:

1. VHF Telemetry Acquisition Aid
2. C-Band Radar
3. Unified S-Band System

Air to ground voice capability is provided on both VHF and Unified S-Band. Magnetic recorders, voice, and chart recorders are available at each site to record PCM telemetry, TV, voice and analog event status information. TV monitors are available to display only slow scan TV from the spacecraft. Inputs to the telemetry processors from remote stations and the MCC-H can be stored in the telemetry processor. Up-data commands from console operators or from MCC-H operators are converted into computer instructions by the console computer interface adapter.

**Table 10**  
**Ground Station System Equipment**

EQUIPMENT		STATIONS																																	
		CAPE KENNEDY	PATRICK AFB	VALKARIA	GRAND BAHAMA	CHERRY POINT	ELEUTHERA	WALLOPS ISLAND	GRAND TURK	BERMUDA	ANTIGUA	ATLANTIC SHIP	CANARY ISLAND	ASCENSION ISLAND	MADRID	KANO	PRETORIA	TANANARIVE	INDIAN OCEAN SHIP	CARMANYON	GUAM	PACIFIC OCEAN SHIP	CANBERRA	CANTON ISLAND	HAWAII	POINT ARQUELLO	GOLDSTONE	GUAYMAS	WHITE SANDS	CORPUS CHRISTI	EGLIN AFB	ENTRY SHIPS 1 & 2	CSQ-RKV SHIPS	8 INJECTION A/C	
UNIFIED S-BAND SYSTEM		D 30'		S 30'					S 30'	S 30'	D 30'	S 30'	D 30'	D 30'	D 30'				S 30'	D 30'	D 30'	D 30'	D 30'		D 30'	D 30'	D 30'	S 30'	S 30'	S 30'	S 12'				
TRACKING	FPQ-6	X	X		X		X	X	X	X	X			X					X	X		X			X	X			X		X				
	FPS-16 MPS-26 TPQ-18 MISTRAM AZUSA GLOTRAC VERLORT USB-RANGING & DOPPLER	X X X X X X X		X		X	X		X	X	X	X	X	X	X		X		X	X	X	X	X		X	X	X		X		X				
TELEMETRY	VHF ANTENNA	X						X	X	X	X	X	X	X		X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
	TLM-18 AGAVE TELTRAC VHF RECEIVERS UNIFIED S-BAND	X X X X X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ACQUISITION	TELTRAC	X			X			X	X	X	X	X	X	X		X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
	TLM-18 AGAVE ACQUISITION BUS USB ANTENNA	X X X X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
A/G VOICE	HF XMTR/RCVR	X			X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	VHF XMTR/RCVR UNIFIED S-BAND	X X		X X				X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X
COMMAND	UHF COMMAND	X						X	X	X	X	X	X	X	X				X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
	DIGITAL COMMAND DRED DRUL UNIFIED S-BAND	X X X X		X X				X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X
DATA DECOM	PCM DECOM	X			X			X	X	X	X	X	X	X	X				X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
	PCM SIMULATOR PAM-PDM DECOM FM/FM DECOM	X X X		X X				X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X
ON-SITE DATA PROCESSOR	TELEMETRY	X			X			X	X	X	X	X	X	X	X				X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
	COMMAND	X X		X X				X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X
RECORDERS	MAG TAPE - DATA	X			X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	MAG TAPE - VOICE OSCILLOGRAPHIC EVENT	X X X		X X X				X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X
CONSOLES AND DISPLAYS	CONSOLES							X				X	X	X					X	X	X	X													
	CSM SYSTEM LEM SYSTEM LEM/S-IV B SYSTEM AEROMED MONITOR CAPCOM MLO FAST ACCESS FILE FLT DYNAMICS GROUP DISPLAYS	X X X X X X X X		X X X X X X X X				X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X	X X X X X X X X		
TELEVISION	MONITOR	X			X			X	X	X		X	X	X	X					X	X		X												
	SCAN CONVERTER USB TELEVISION (GRD XMTR TO MCC-14)	X X X		X X X				X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X	X X X
SPAN	SOLAR RADIO TELESCOPE																																		
	SOLAR OPTICAL TELESCOPE																																		

NOTE  
S = 1 XMTR/2 RCVR  
D = 2 XMTR/4 RCVR

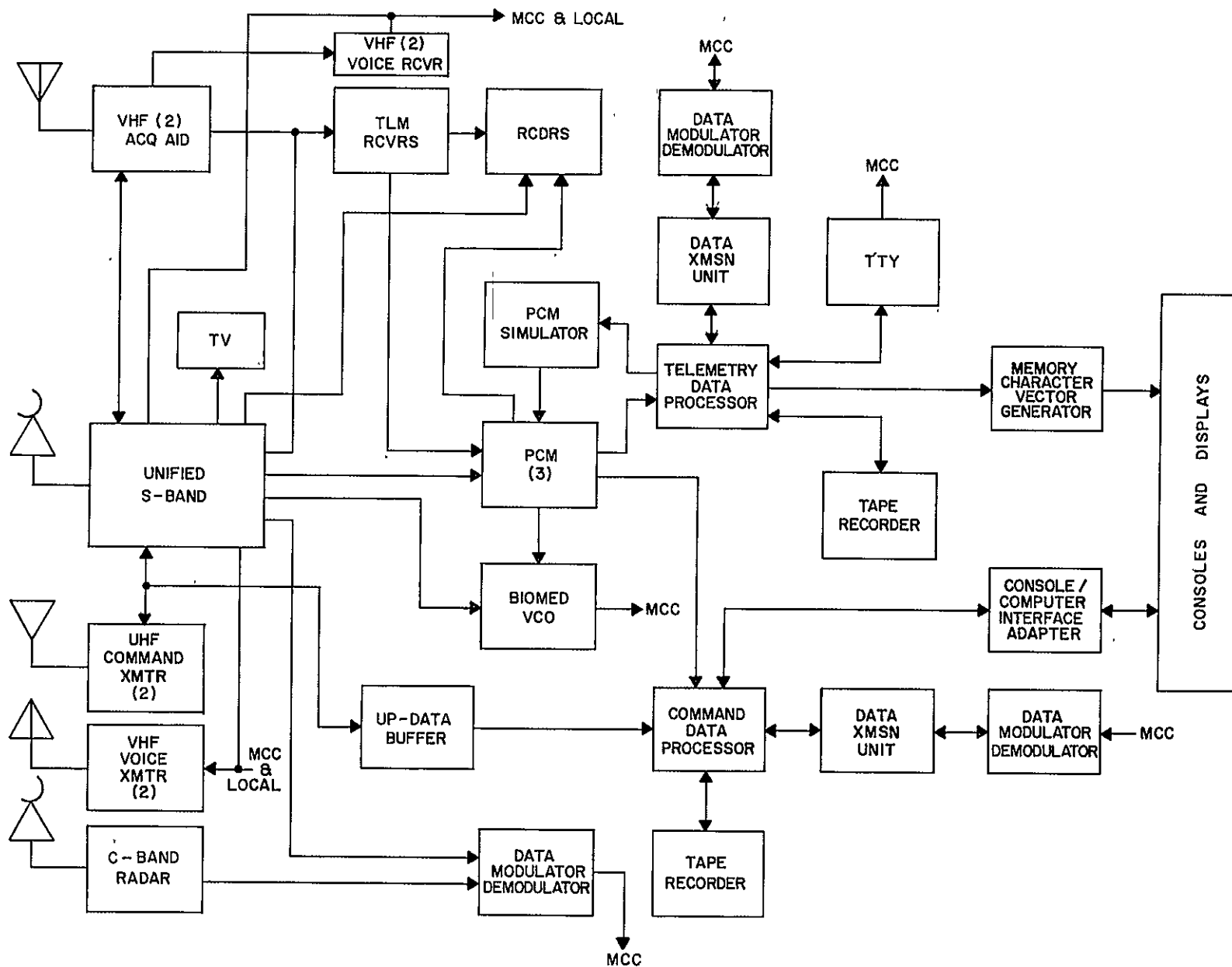


Figure 9—Typical Remote Site Block Diagram

A significant aspect of the MSFN capabilities is the quantity of data that can be handled at the stations. It is important to note that the Unified S-Band stations are not limited to handling maximum data transmission rates of 51.2 K bits per second; the present limitation of the Apollo CSM and LEM spacecraft. The USB ground stations data handling capabilities are shown in Table 11. Data rates of 200 K bits per second per USB receiver can be processed at each USB station. The PCM decommutation system is capable of handling up to 1 megabit per second per PCM system.

### SHIPS

Five (5) tracking ships are equipped to support the Apollo tracking network. These ships will include Apollo support instrumentation for acquisition, communications, tracking, command, telemetry reception, recording, processing, display, and retransmission. They will also include general-purpose instrumentation capability for the National Range.

These ships will support the following mission phases:

1. Coverage of selected areas to maintain contact with the spacecraft during critical phases of the mission, such as, insertion, injection, and re-entry.
2. Insertion of the spacecraft into a near-earth parking orbit.
3. Parking orbit in-flight checkout to assure spacecraft readiness for lunar trajectory injection.
4. The ships will supply post-injection support of the spacecraft into lunar trajectory from a parking orbit until MSFN 85 ft station coverage of the lunar trajectory is reached.
5. Re-entry using two (2) ships in Pacific Ocean positions which can make contact before spacecraft return into the earth's atmosphere, and which can cover spacecraft "skip-out" to attain final re-entry coverage.

On the recovery ships, the telemetry system, data handling, display, and control center are considerably reduced from those of the insertion/injection ships.

Figure 10 is a simplified block diagram of a complete system.

Table 11  
MSFN USB-Equipped Ground Station Data Handling Capability

Stations	*Usb Downlink Receiver/Demod	PCM Demod	Data Processing	Wide-Band Data and TV Tape Recording	**Ground Data Transmission	Usb Uplink
Cape Kennedy (D) 4 Downlink Carriers	200 Kb/Link $\times$ 4 = 800 Kb	1 Meg B/System $\times$ 3 = 3 Meg B	Word Storage 32 K $\times$ 2 = 64 K Transfer Rate 500 K (30 Bit Words) Per Second	1.5 Mc/Chan/System 3 Systems	(1) Chan at 40.8 Kb (1) TV	200 Bps - Info Bit Rate 1000 Bps - Sub Bit Rate
Grand Bahama (S) 3 Downlink Carriers	200 Kb/Link $\times$ 3 = 600 Kb	1 Meg B/System $\times$ 3 = 3 Meg B	↑	↑	(1) Chan at 40.8 Kb	↑
Bermuda (S) 3 Downlink Carriers	200 Kb/Link $\times$ 3 = 600 Kb	1 Meg B/System $\times$ 4 = 4 Meg B		↓	(3) Chan at 2.4 Kb	
Antigua (S) 3 Downlink Carriers	200 Kb/Link $\times$ 3 = 600 Kb	1 Meg B/System $\times$ 3 = 3 Meg B		1.5 Mc/Chan/System 2 Systems	(3) Chan at 2.4 Kb	
Atlantic Ship (D) 4 Downlink Carriers	200 Kb/Link $\times$ 4 = 800 Kb	↑		↑		
Canary Island (S) 3 Downlink Carriers	200 Kb/Link $\times$ 3 = 600 Kb			↓	(2) Chan at 2.4 Kb	
Ascension (D) 4 Downlink Carriers	200 Kb/Link $\times$ 4 = 800			↓	(2) Chan at 2.4 Kb	
Madrid (D) 4 Downlink Carriers	↑			1.5 Mc/Chan/System 2 Systems	(3) Chan at 2.4 Kb	
Carnarvon (D) 4 Downlink Carriers				1.5 Mc/Chan/System 3 Systems	(2) Chan at 2.4 Kb	
Guam (D) 4 Downlink Carriers				1.5 Mc/Chan/System 2 Systems	(3) Chan at 2.4 Kb	
Pacific Ship (D) 4 Downlink Carriers				1.5 Mc/Chan/System 2 Systems	-	
Canberra (D) 4 Downlink Carriers				1.5 Mc/Chan/System 2 Systems	(3) Chan at 2.4 Kb	
Hawai (D) 4 Downlink Carriers	↓			1.5 Mc/Chan/System 3 Systems	(3) Chan at 2.4 Kb	
Goldstone (D) 4 Downlink Carriers	200 Kb/Link $\times$ 4 = 800 Kb			1.5 Mc/Chan/System 2 Systems	(3) Chan at 2.4 Kb (1) TV	
Guaymas (S) 3 Downlink Carriers	200 Kb/Link $\times$ 4 = 800 Kb			1.5 Mc/Chan/System 3 Systems	(2) Chan at 2.4 Kb	
Corpus Christi (S) 3 Downlink Carriers	200 Kb/Link $\times$ 3 = 600 Kb			1.5 Mc/Chan/System 3 Systems	(3) Chan at 2.4 Kb	
Entry Ship #1 (S) 3 Downlink Carriers	200 Kb/Link $\times$ 3 = 600 Kb	↓	↓	1.5 Mc/Chan/System 2 Systems	-	↓
Entry Ship #2 (S) 3 Downlink Carriers	200 Kb/Link $\times$ 3 = 600 Kb	1 Meg B/System $\times$ 3 = 3 Meg B	Word Storage 32 K $\times$ 2 = 64 K Transfer Rate 500 K (30 Bit Words) Per Second	1.5 Mc/Chan/System 2 Systems	-	200 Bps - Info Bit Rate 1000 Bps - Sub Bit Rate

\* Limiting Data Transfer Spacecraft/Ground Station

\*\* Limiting Real-Time Data Transfer to MCC-H

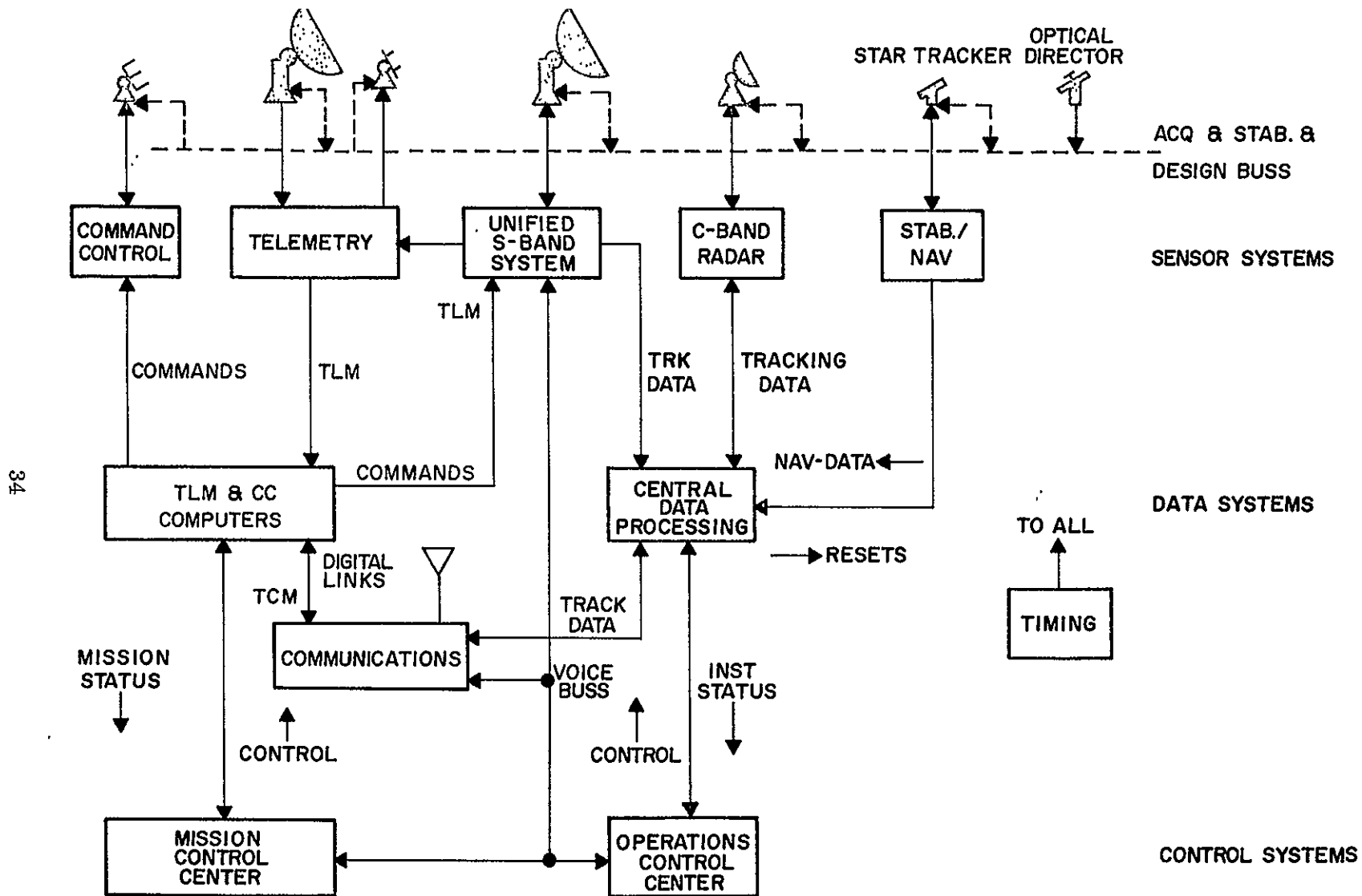


Figure 10—Apollo Ships Simplified Block Diagram

## COMMUNICATIONS AIRCRAFT

Eight C-135A aircraft are being instrumented for use by GSFC during the Apollo mission. These aircraft will be deployed to cover the S IV-B injection burn period during any of the three consecutive potential injection orbits of the mission.

Also, these aircraft will participate in the re-entry phase by providing telemetry recording and voice communications during the interval between the termination of the first blackout and the recovery phase.

### b. Satellite Tracking and Data Acquisition Network (STADAN)

#### (1) Introduction

The primary purpose of the STADAN is to receive data from scientific satellites and to produce tracking information for orbit computation. The locations of the STADAN stations are shown in Figure 8. Although no augmentation of the STADAN (except Fairbanks) for AES is presently planned, this material is presented to give a complete picture of existing network capabilities. Most of the equipment in the STADAN has been designed for use by many programs, with emphasis on quick adaptability to the differing requirements of several simultaneously-orbiting spacecraft. Most programs do not require data from all STADAN stations, so the specific capabilities of each station have been tailored to differing levels of performance. The result is that no two stations are identical in terms of either equipment types or total data capacity.

Operation of the STADAN is centered at GSFC. All stations are connected to GSFC through teletype (TTY) and voice (SCAMA) lines. Fairbanks and Rosman also have wide-band microwave links to GSFC for real-time data transmission. Certain "quick-look" telemetry data is sent to GSFC over TTY lines in near-real-time, but most telemetry data is recorded and sent to GSFC by mail. Tracking data is sent by TTY in near-real-time.

Present plans call for the closing of four stations by the end of CY 1966: Blossom Point, College, E. Grand Forks, and Woomera. Blossom Point will be moved to GSFC to become a test facility. College, now located near Fairbanks, will be co-located with the 85-foot dish designated in the chart as Fairbanks. E. Grand Forks will be closed and the equipment distributed. Woomera will be co-located with Canberra.

## (2) Network Equipment

The STADAN can be considered as consisting of five major systems, namely:

1. 85-foot Data Acquisition Facility (DAF)
2. 40-foot DAF
3. VHF Telemetry System
4. Goddard Range and Range Rate System
5. Minitrack Tracking System

The most obvious distinction between these systems is the type of antenna used. The first three systems all use identical or very similar receivers, transmitters, and data handling equipment. Only the Range and Range Rate and Minitrack systems are completely unique. A particular station may have any combination of the above systems, and the specific configuration of the system will vary depending on the cumulative requirements placed on the station.

The 85-foot and 40-foot DAF are instrumented for telemetry reception at 136 Mc, 400 Mc and 1700 Mc, except the Goldstone 40-foot dish which is exclusively instrumented for use by the Advanced Technology Satellite (ATS) project. These systems have VHF command capability through an auxiliary antenna. This equipment could support AES; however, almost all station equipment except the antenna structure would have to be replaced. Details will be given in Part II of this report.

The VHF Telemetry System would also be of little use to AES. It employs receivers having a maximum bandwidth of 1 Mc and medium-power VHF transmitters.

The Goddard Range and Range Rate System (GR & RR) is better adapted to support of the AES mission than the 85-foot and 40-foot DAF. A modification program now underway will modify the GR & RR frequencies to make it compatible with Apollo, AES, and SGLS. All GR & RR stations will also be equipped with a 30-foot antenna on an X-Y mount. With some additional modifications which would be relatively minor, the GR & RR could be capable of operating as a Unified S-Band System.

Use of the Minitrack system for accurate tracking and orbit computation would require the use of a 136 Mc beacon on-board the spacecraft. Minitrack has the capability of determining an accurate orbit in a period of a few hours.

New developments planned for Minitrack will increase sensitivity, allowing accurate tracking of satellites in synchronous orbits using nominal (100 mw) transmitted power.

Table 12 STADAN Ground Station Systems Summary, tabulates the equipment to be located at each of the stations by the end of CY 1966. Data capacity is also indicated. Some items of special-purpose equipment are also shown, such as mobile-station equipment now located in trailers at Kano and Kauai. This equipment is all 136 Mc and 400 Mc telemetry and not of much interest to AES.

### (3) Contact Time

Contact time for the STADAN GR & RR and Minitrack stations is tabulated separately in Part II of this report.

### (4) Multiple Mission Capability

The STADAN is already managed on a full-time (24 hr.) basis in support of many simultaneous scientific missions.

### (5) STADAN Availability

The expected workload of each STADAN station is tabulated in ref. 6.

Should the study indicate an existing projected heavy workload for a particular STADAN station which would be desirable to augment for AES, it is possible some workload may be temporarily shifted to other stations. Such shifting of workload is presently handled by NETCON at GSFC to satisfy all programs on the basis of established priorities.

## 2. NASCOM NETWORK

Since the inception of NASA in 1958, three tracking and data acquisition networks have been established to satisfy the unique requirement of different types of space missions. The three networks consist of the Manned Space Flight Network (MSFN) and the Satellite Tracking and Data Acquisition Network (STADAN) which are managed by GSFC and the Deep Space Network (DSN) which is managed by the Jet Propulsion Laboratory (JPL) in California. During evolution and development of the three networks, their ground communications requirements became more complex because of the increasing number and various types of satellites and spacecraft. To improve communications efficiency and reliability, a unified

Table 12  
STADAN Ground Stations System Equipment

		FAIRBANKS	GOLDSTONE (MOJAVE)	BLOSSOM PT.	CANBERRA	CARNARVON	COLLEGE	E. GRAND FORKS	FT. MYERS	JOHANNESBURG	LIMA	QUITO	ROSMAN	ST. JOHNS	SANTIAGO	TANANARIVE	WINKFIELD	WOOMERA	KANO	KAUAI
TRACKING SYSTEMS	MINITRACK	-	1	1	-	-	1	1	1	1	1	1	-	1	1	-	1	1	-	-
	GR&RR	1	-	-	-	1	-	-	-	-	-	-	1	-	1	1	-	-	-	-
TELEMETRY ANTENNAS	85 FT DISH AUTOTRACK	1	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
	40 FT DISH AUTOTRACK	1	1	-	-	-	-	-	-	1	-	1	-	-	1	1	-	-	-	-
	136 MC SATAN AUTOTRACK	2	1	1	2	-	-	-	1	1	1	1	2	-	2	2	1	-	-	-
	136 MC YAGI MANUAL	-	1	-	-	-	2	1	2	2	2	1	-	2	1	-	2	2	1	1
COMPUTERS	PB-250	1	1	-	1	-	-	-	-	1	-	1	1	-	1	-	-	-	-	-
TELEMETRY RECEIVERS	SPECIAL PURPOSE	2	-	-	-	-	2	-	2	-	-	-	2	-	-	2	-	-	2	2
	DIVERSITY TELEMETRY	10	7	2	8	-	-	-	4	7	3	7	12	-	7	7	4	2	-	-
	MOD I TELEMETRY	-	2	2	-	-	2	2	2	2	3	2	5	2	-	-	2	2	-	-
	PHASE DEMODULATOR	9	6	3	7	-	1	1	4	7	3	7	12	-	7	7	4	3	1	1
PCM DEMODULATORS	200 KBPS CAPACITY	1	-	-	-	-	-	-	-	1	-	1	1	-	1	-	-	-	-	-
	320 KBPS CAPACITY	-	1	1	-	-	1	1	1	1	1	1	-	1	1	-	1	1	-	-
	1 MEG BPS CAPACITY	-	2	-	2	-	-	-	1	-	1	-	1	-	-	2	1	-	-	-
RECORDERS	8 CHANNEL TAPE	8	6	5	6	-	3	2	6	8	2	8	10	2	8	7	6	4	2	2
	8 CHANNEL PAPER	5	4	2	6	-	3	3	4	4	2	7	8	2	5	7	3	2	1	1
	6 CHANNEL OPTICAL	1	1	1	1	-	1	1	1	1	1	2	2	1	2	2	1	1	-	-
VHF COMMAND	ENCODER CONSOLE	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	250 WATT AM	-	1	1	-	-	2	1	2	2	2	2	-	2	2	-	2	2	1	1
	2.5 KW AM	4	2	2	2	-	-	-	2	-	2	2	4	-	-	4	2	-	-	-
	5.0 KW AM	2	-	-	2	-	-	-	-	2	-	2	2	-	2	-	-	-	-	-
	148 MC 23 DB ANTENNA	2	1	1	2	-	-	-	1	1	1	1	2	-	1	2	1	-	-	-
	148 MC 10 DB ANTENNA	1	1	1	-	-	1	1	2	1	1	1	2	2	1	-	2	1	1	1

NOTES:

- AUTOTRACK RECEIVERS AND PROGRAMMERS ARE PROVIDED AS PART OF THE BASIC TELEMETRY ANTENNAS AS APPROPRIATE.
- DIVERSITY TELEMETRY RECEIVER MAXIMUM BANDWIDTH IS 3 MC IF (1.5 MC BASEBAND).
- MOD I TELEMETRY RECEIVER MAXIMUM BANDWIDTH IS 1 MC IF (500 KC BASEBAND).
- PHASE DEMODULATOR MAXIMUM BANDWIDTH IS 400 KC IF (200 KC BASEBAND). NEW UNITS HAVING A 3 MC IF BANDWIDTH (1 MC BASEBAND) ARE BEING DEVELOPED, BUT QUANTITIES PER STATION ARE NOT FINALIZED.
- TAPE RECORDER BANDWIDTH - 250 KC.
- PAPER RECORDER BANDWIDTH - 100 CPS.
- OPTICAL RECORDER BANDWIDTH - 4800 CPS.
- TRANSMITTER RESPONSE - PCM/AM/AM TO 1200 CPS MOD RATE.
- SPECIAL PURPOSE RECEIVERS HAVE VARIOUS PLUG-IN BANDWIDTH MODULES WITH A MAXIMUM BANDWIDTH OF 1 MC.

ground communications network was developed. This network, which provides all NASA programs with operational communications support, has been designated as the NASA Communications Network (NASCOM).

This improvement of communications reliability, in conjunction with economic considerations, provided an increasing and compelling need to share existing circuits and facilities of the MSFN, STADAN, and the DSN. This in turn led to the concept of a primary switching center where circuit sharing and flexibility with centralized facilities control could be attained. Consequently, the total NASCOM communications resources became available for utilization in support of any mission. Thus, alternate communication channels can be provided in the event of isolated circuit malfunction. As a result of circuit sharing, NASCOM circuits are used constantly. Continual utilization and exercise of circuits and equipments is the best method of ensuring a high degree of network reliability. Because the NASCOM Network combines requirements of various users, facilities in excess of those required on an individual basis are available to a project as backup, with attendant diverse routing advantages.

#### a. Communications Capabilities

Figure 11 shows the various MSFN and STADAN tracking and data acquisition stations which were considered in the GSFC investigation of the ground support capability for the AES program. The number and type of communications circuits are shown in the individual blocks under the four letter station indicator. These communication capabilities either exist or are planned for in the 1968-70 time frame.

##### (1) Voice Communications (V)

Four-wire voice communications are furnished between GSFC and all of the MSFN and to many of the STADAN ground stations. Four-wire voice circuits are also extended from GSFC to the various control centers such as MCC-H at Houston, Texas. The SCAMA (Station Conferencing and Monitoring Arrangement) board at GSFC has the capability of making any point-to-point voice connection or of connecting an unlimited number of remote ground stations into a voice conference loop. In the case of an Apollo mission, a voice conference loop will be used primarily by the flight controllers at MCC-H to monitor and transmit over the remote site air-ground equipment to the astronauts, and for coordination between MCC-H and the remote ground stations.

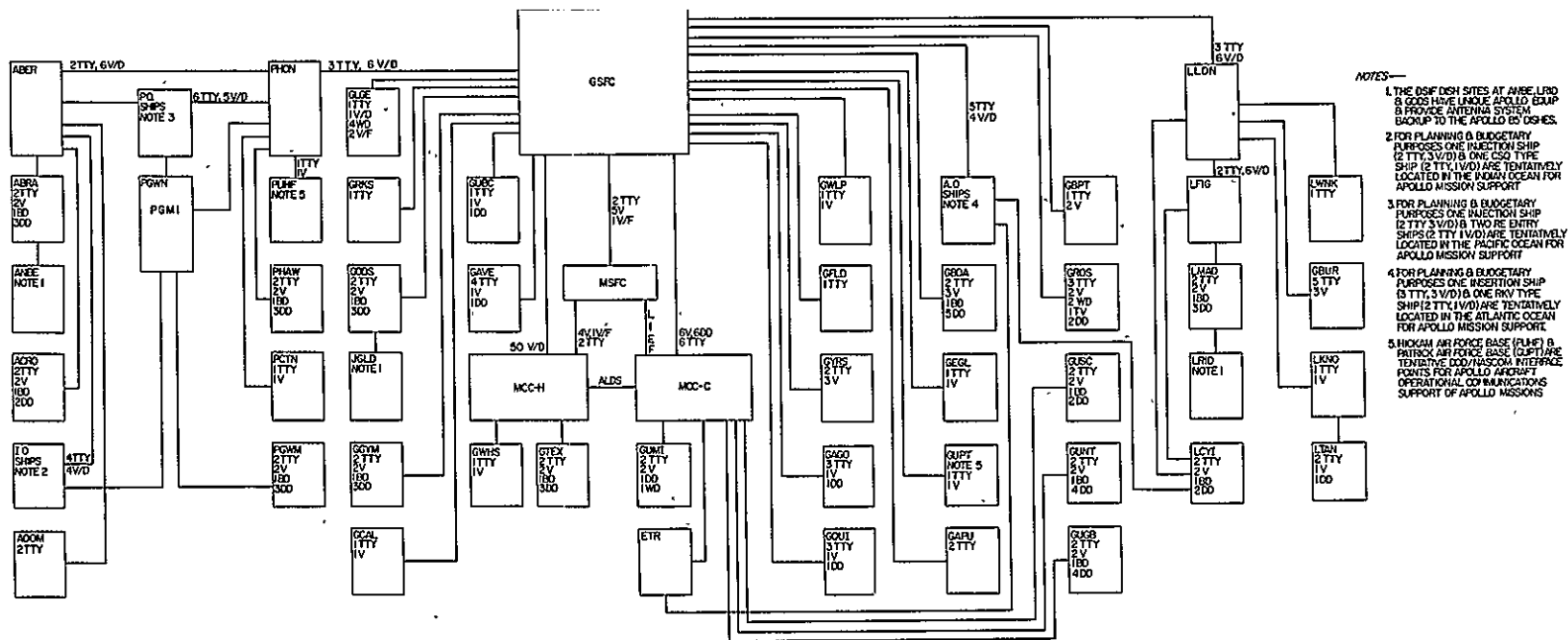


Figure 11–NASCOM Ground Communications Network

## (2) Teletype Communications (TTY)

Teletype communications has provided the backbone communications for the global NASA space program. Full-duplex (FDX) teletype circuits, to enable a simultaneous transmit and receive capability, are used to connect all ground stations of the MSFN and STADAN to GSFC and thus to the various control centers. Teletype speeds of 60 wpm are normally used; however, it is desirable to increase this to 100 wpm wherever feasible. These circuits are used for the receipt of radar tracking data, telemetry summary messages from the ground stations, and administrative and operational control traffic between the ground stations and the various centers.

## (3) Biomedical Data (BD)

Dual-purpose, full-duplex voice/data circuits are required for transmission of analog biomedical data from each astronaut to the MCC-H when the remote site has spacecraft acquisition. The circuits will provide additional two-way voice communication capability during non-acquisition periods.

## (4) High-Speed Digital Data (DD)

High-speed data circuits are required between USB ground stations and ships of the MSFN and certain ground stations of the STADAN and their respective control centers for real-time transmission of telemetry and command data. Radar tracking data is required from some stations at a high-speed data rate. As a general rule, telemetry data from the remote sites is required at a rate of 1200/2400 bps. Up data and command data to the remote sites will be transmitted at a rate of 1200 bps.

## (5) Wide-Band Data (WD)

Wide-band telemetry data of 40.8 kilobits per second is required from the Apollo 30' Unified S-Band sites at Merritt Island and at Grand Bahama, and from the down-range ETR sites during the pre-launch and launch phases of the missions. Wide-band telemetry data is also required from the Apollo site at Merritt Island during the orbital phases of the missions.

## (6) Television (TV)

Television transmission is required in both directions between KSC and the MCC-H for mission time video transmission and reception of the pre-launch activities at the launch complex and the lift-off powered flight phases. Television circuits are also required between the launch complex and MSFC for pre-launch checkout of the booster systems.

(7) Voice/Facsimile (V/F)

Alternate voice/facsimile facilities are required between the various control centers and program centers for the transmission and receiving of engineering charts, diagrams, and schematics. In addition, these facilities are needed between the control centers and the National Meteorological Center at Suitland, Maryland, for the transmission of weather charts, graphs, and other information pertaining to weather and meteoric conditions.

b. Instrumentation at GSFC and Sub-Switching Centers

(1) Voice/Data Switchers

A voice switching, conferencing, and monitoring facility, which is functionally similar to the SCAMA II board at GSFC, is being installed at the NASCOM sub-switching centers located in Canberra, Guam, Hawaii, London, and Madrid. This system operates with SCAMA II to provide a flexible and rapid means of connecting together voice/data lines on a point-to-point or conferenced basis. During voice conferences the attendant can add or remove conferees and can change the transmission of certain conferees from talk/listen to listen only. Preset conferences and preset point-to-point connections provide for direct control of the system circuits by the SCAMA II operator. In addition, high-speed data and standard facsimile transmissions can be switched. This facility will permit rapid interconnection and conferencing of circuits to and from the overseas areas to realize maximum permissible sharing of all circuit resources and for circuit restoration.

It was found necessary in the design of the worldwide data transmission system to adopt the approach of data regeneration at all sub-switching centers. With this approach, the longest circuits or circuit legs which must meet the end-to-end equalization specifications are between sites and sub-switching centers, between sub-switching centers, or between sub-switching centers and GSFC. Another very important advantage of this arrangement is that any combination of trunks, tributaries, or alternate routes can be interconnected to provide data transmission between any two points in the network. This flexibility obviously would not be available if regeneration was not employed and an attempt were made to maintain a quite stringent end-to-end circuit equalization characteristic.

## (2) Communication Processors for Teletype Messages

Teletype communications, being a record or data form of communication, lends itself particularly well to circuit and message sharing through the use of store and forward or buffer techniques. Circuit-sharing arrangements are currently planned at the Canberra and London sub-switching centers through the use of automatic solid-state store and forward message switching equipment similar to but not as large as the Univac 490 system installed at the primary switching center at GSFC. Speed conversion and interleaving of message segments is performed on teletype messages coming into these sub-switching centers and transmitted to GSFC over high-speed data circuits. The Univac 490 at GSFC reassembles the individual teletype messages and automatically routes them on to their proper destination.

## MISSION COVERAGE ANALYSIS

### 1. General

Sample trajectories have been studied for typical missions in each of the AES mission categories. The samples were studied over a period of three days or forty eight orbits. In general, the analyses were limited to forty eight orbits for a given mission since, after this period, the trajectories began to repeat very closely the previous forty eight orbits.

The results of the analyses are reported in this chapter. An orbit is defined as the portion of a trajectory starting at the eightieth meridian West, and terminating at the same meridian after approximately encircling the earth.

The total time during which the spacecraft is in contact with the network has been computed for each orbit of the sample trajectory. The periods in which no standard four minute contact was made over a two hour interval have been listed, and the duration of the interval without contact is given.

Details of the contact time and data transfer time will be shown in Part II of the GSFC AES Study.

### 2. Mission Coverage (Visibility)

Mission coverage (visibility) analyses (maps of ground traces, and bar graphs of station contact time) have been made for all types of missions

which have been discussed in Flight Schedule AE 65-1 and supplemented by correspondence from Office of Manned Space Flight (OMSF) and Office of Tracking and Data Acquisition (OTDA), NASA Headquarters. There is one exception; the mission utilizing a synchronous orbit with 28.5 degree inclination was not analyzed in detail, because the trajectory data (ref. 7) for this orbit shows that the maneuvers occur:

- a. over the Madagascar area, where there is a tracking ship; and
- b. at synchronous altitude in the proximity of Tahiti where they are visible from Hawaii, Australia, and continental U.S.A.

Hence, it can be seen that this type orbit would be well covered by the MSFN.

In summary, the types of orbital missions analyzed were:

- a. 200 nm altitude, circular orbits with inclinations of 96.5°, 90°, 81.5°, 50.3°,\* and 28.5°
- b. synchronous equatorial orbits
- c. a sample lunar trajectory

Shown in Figures 12, 14, 16, 18, and 20 are sample ground traces for the missions using 200 nm earth orbits having inclinations of 96.5°, 90°, 81.5°, 50.3°, and 28.5°, respectively.

The launch trajectories and insertion conditions were obtained from the TRW Space Technology Laboratories study (ref. 7) for 96.5°, 90°, and 28.5° inclined orbits, and were estimated for the 81.5° and 50.3° inclined orbits.

In numbering the orbits, the criteria used was that an orbit begins and ends at the 80°W longitude meridian.

Figure 22 gives ground traces of the trajectories used to insert the AES spacecraft into a synchronous equatorial orbit at a point approximately north of Australia. The plane changes, transfer trajectories, and

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\*Although this mission is not included in the latest schedules, it is incorporated here because it was analyzed as part of previous schedules.

spacecraft altitudes are indicated on the ground traces. This particular choice of "ascent" trajectories into the synchronous equatorial orbit was chosen for two reasons. First, the choice of plane changes was the result of a study by TRW Space Technology Laboratories (ref. 7) for optimizing the payload into the synchronous equatorial orbit (see also ref. 5). Second, during the descent mode, a drift maneuver of minimal time and energy prior to deorbit will place the spacecraft in position at 100° E longitude for optimum reentry. An optimum reentry is considered to be a trajectory requiring minimum energy and terminating in the nominal Apollo impact area. The ground trace for this return trajectory is shown in Figure 24.

Figure 26 gives the ground traces for a sample lunar trajectory which has one earth parking orbit and a translunar trajectory. The times and altitudes are shown at discrete points on the ground traces to facilitate interpretation. The mission coverage (visibility) of the AES lunar missions are assumed to be similar to those of the Apollo missions.

Sample bar graphs of station contact times for the corresponding ground traces are given in Figures 13, 15, 17, 19, 21, 23, 25, and 27. In the case of earth orbital missions these bar graphs show the station contact times for all those stations (both MSFN and STADAN) which can "see" the spacecraft, regardless of the equipment which is available. This is for completeness and to provide data which may be useful in making network augmentation trade-off and cost effectiveness studies. In the case of lunar missions, only the MSFN stations with USBS were considered.

More complete sets of maps with ground traces, station contact time bar graphs, and station contact time tables will be given in Part II of this report.

# **APOLLO EXTENSION SYSTEM** **POLAR ORBITS, $i = 96.5^\circ$ , $H = 200$ nm $\epsilon \geq 5^\circ$** **ORBITS 1 through 18, FIRST DAY**

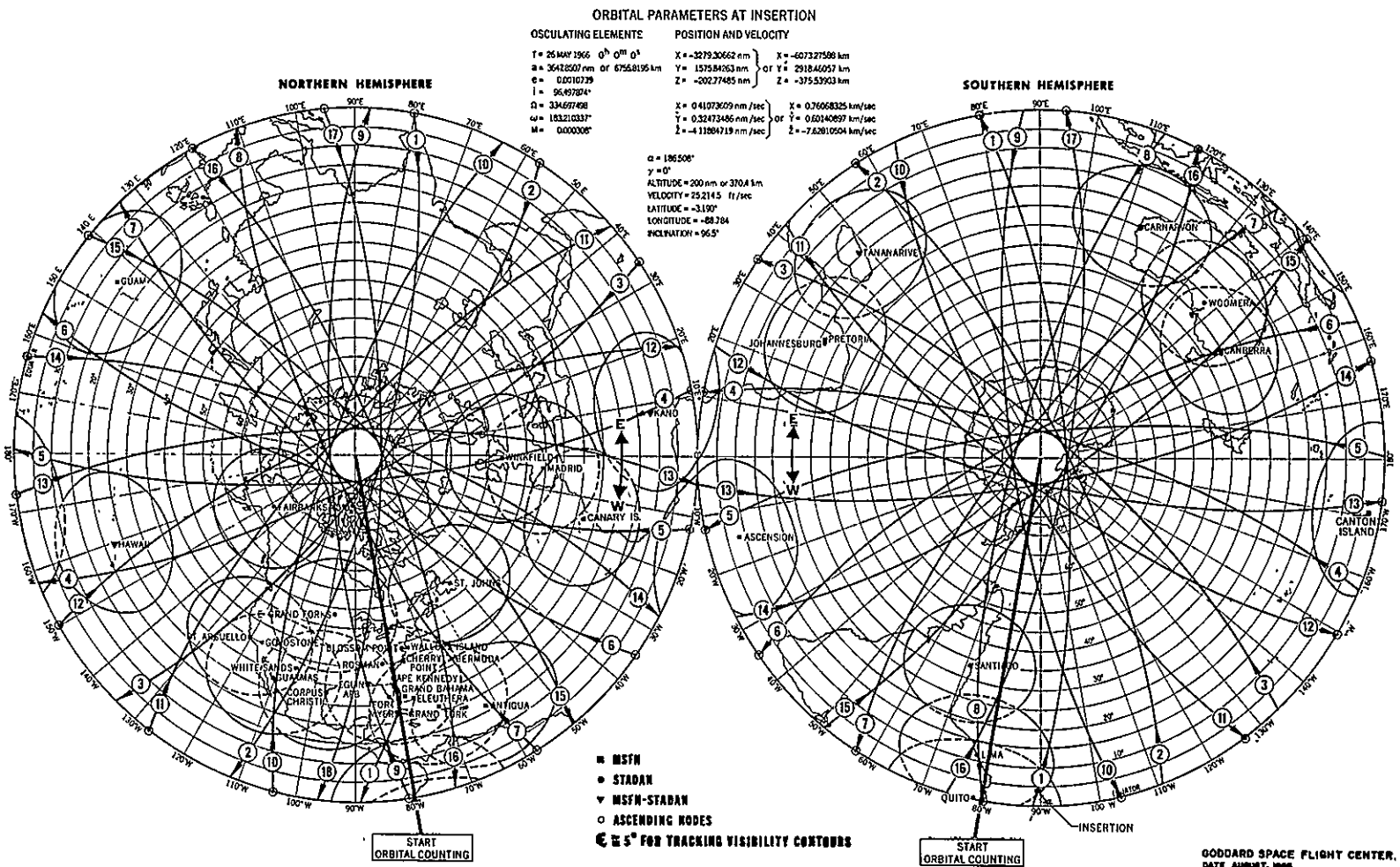


Figure 12-Apollo Extension System Polar Orbits,  $i = 96.5^\circ$ ,  $H = 200$  nm,  $\epsilon \geq 5^\circ$ , Orbits 1 through 18, First Day



# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR POLAR ORBITS

$i = 96.5^\circ$ ,  $H = 200\text{nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 1 to 9, FIRST DAY

### ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS		POSITION AND VELOCITY	
T = 26 MAY 1966, 0 <sup>h</sup> 0 <sup>m</sup> 0 <sup>s</sup>	X = -3279.30662 nm	X = -6073.27588 km	$\alpha = 186.508^\circ$
a = 36478507 nm OR 6755.8195 km	Y = 1575.84263 nm	OR Y = 2918.46057 km	$\gamma = 0^\circ$
e = 0.0010739	Z = -202.77485 nm	Z = -375.53903 km	ALTITUDE = 200 nm or 370.4 km
i = 96.497874°			VELOCITY = 25,214.5 ft/sec
$\Omega = 334.697498^\circ$	$\dot{X} = 0.41073609 \text{ nm/sec}$	$\dot{X} = 0.76068325 \text{ km/sec}$	LATITUDE = -3.190°
$\omega = 183.210337^\circ$	$\dot{Y} = 0.32473486 \text{ nm/sec}$	OR $\dot{Y} = 0.60140897 \text{ km/sec}$	LONGITUDE = -88.784°
M = 0.000308°	$\dot{Z} = -4.11884719 \text{ nm/sec}$	$\dot{Z} = -7.62810504 \text{ km/sec}$	INCLINATION = 96.5°

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

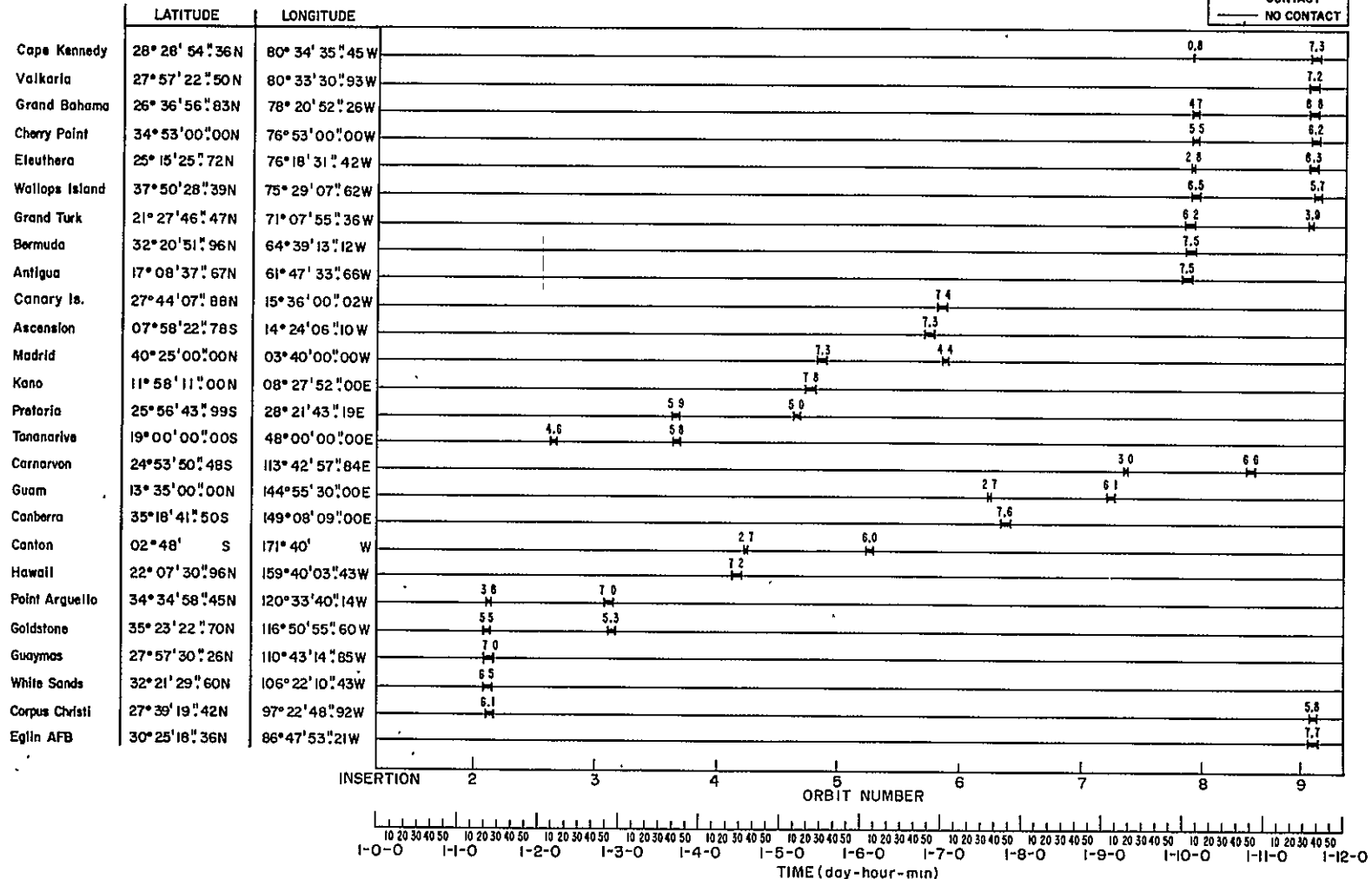


Figure 13—Apollo Extension System Station Coverage for Polar Orbits,  $i = 96.5^\circ$ ,  $H = 200 \text{ nm}$ ,  
 $\epsilon \geq 5^\circ$ , Orbits 1 to 9, First Day

# **APOLLO EXTENSION SYSTEM** **STATION COVERAGE FOR POLAR ORBITS** *i* = 96.5°, H = 200 nm, $\epsilon \geq 5^\circ$ , ORBITS 1 to 9, FIRST DAY

## ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS		POSITION AND VELOCITY	
T = 26 MAY 1966, 0 <sup>h</sup> 0 <sup>m</sup> 0 <sup>s</sup>	X = -3279.30662 nm	X = -6073.27588 km	$\alpha = 186.508^\circ$
a = 3647.8507 nm or 6755.8196 km	Y = 1575.84263 nm	or Y = 2918.46057 km	$\gamma = 0^\circ$
e = 0.0010739	Z = -202.77485 nm	Z = -375.53903 km	ALTITUDE = 200 nm or 370.4 km
i = 96.497874°			VELOCITY = 25 214.5 ft/sec
$\Omega = 334.697498^\circ$	$\dot{X} = 0.41073609$ nm/sec	$\dot{X} = 0.76068325$ km/sec	LATITUDE = -3.190°
$\omega = 183.210337^\circ$	$\dot{Y} = 0.32473486$ nm/sec	or $\dot{Y} = 0.60140897$ km/sec	LONGITUDE = -88.784°
M = 0.000308°	$\dot{Z} = -4.11884719$ nm/sec	$\dot{Z} = -7.62810504$ km/sec	INCLINATION = 96.5°

KEY:  
 MINUTES OF CONTACT  
 — NO CONTACT

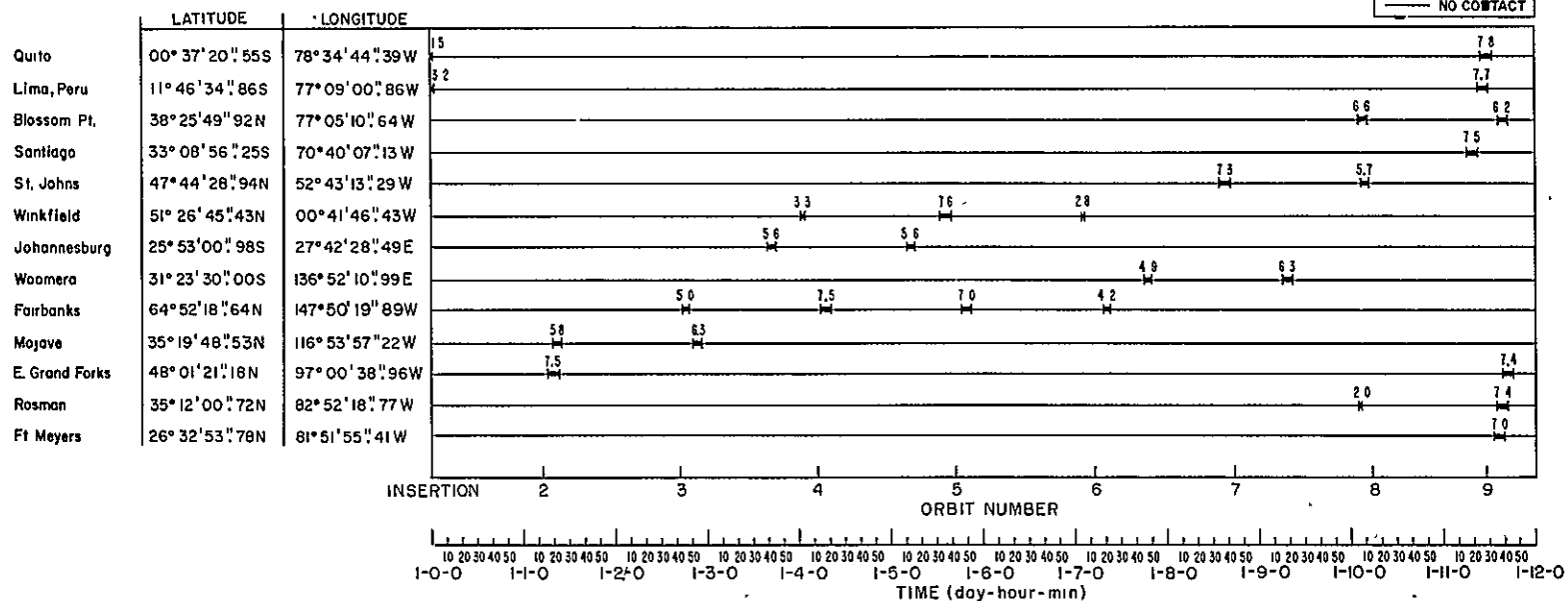


Figure 13 (Continued)—Apollo Extension System Station Coverage for Polar Orbits, *i* = 96.5°,  
 H = 200 nm,  $\epsilon \geq 5^\circ$ , Orbits 1 to 9, First Day

# **APOLLO EXTENSION SYSTEM** **POLAR ORBITS, $i = 90^\circ$ , $H = 200\text{nm}$ , $\epsilon \geq 5^\circ$** **ORBITS 1 through 16, FIRST DAY**

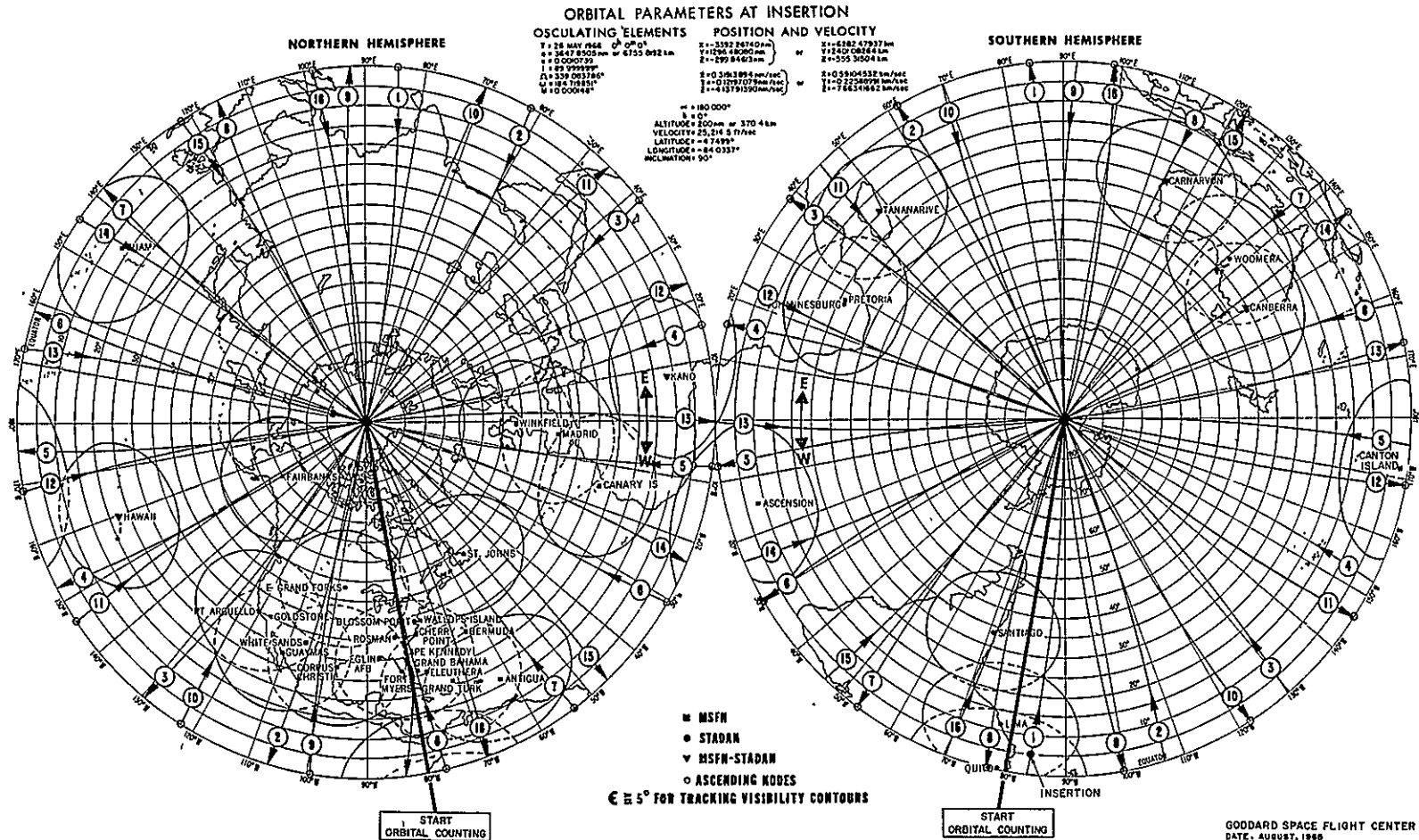


Figure 14—Apollo Extension System Polar Orbits,  $i = 90^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 through 16, First Day

# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR POLAR ORBITS

$i = 90^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 1 to 9, FIRST DAY

### ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS		POSITION AND VELOCITY	
T = 26 MAY 1966 0 <sup>h</sup> 0 <sup>m</sup> 0 <sup>s</sup>		X = -3392 26740 nm	X = -6282 47937 km
a = 3647 8505 nm or 6755 8192 km		Y = 1296 48080 nm	Y = 2401 08264 km
e = 0.0010739		Z = -299 64613 nm	Z = -555 31504 km
i = 89.999999°			ALTITUDE = 200 nm or 370.4 km
$\Omega = 339.083786^\circ$		X = 0.31913894 nm/sec	X = 0.59104532 km/sec
$\omega = 184.719851^\circ$		Y = -0.12197073 nm/sec	Y = -0.23509991 km/sec
M = 0.000168°		Z = -4.11791390 nm/sec	Z = -7.66341662 km/sec
			VELOCITY = 25,214.5 ft/sec
			LATITUDE = -4.7499°
			LONGITUDE = -84.0337°
			INCLINATION = 90°

KEY	MINUTES OF CONTACT
—	NO CONTACT

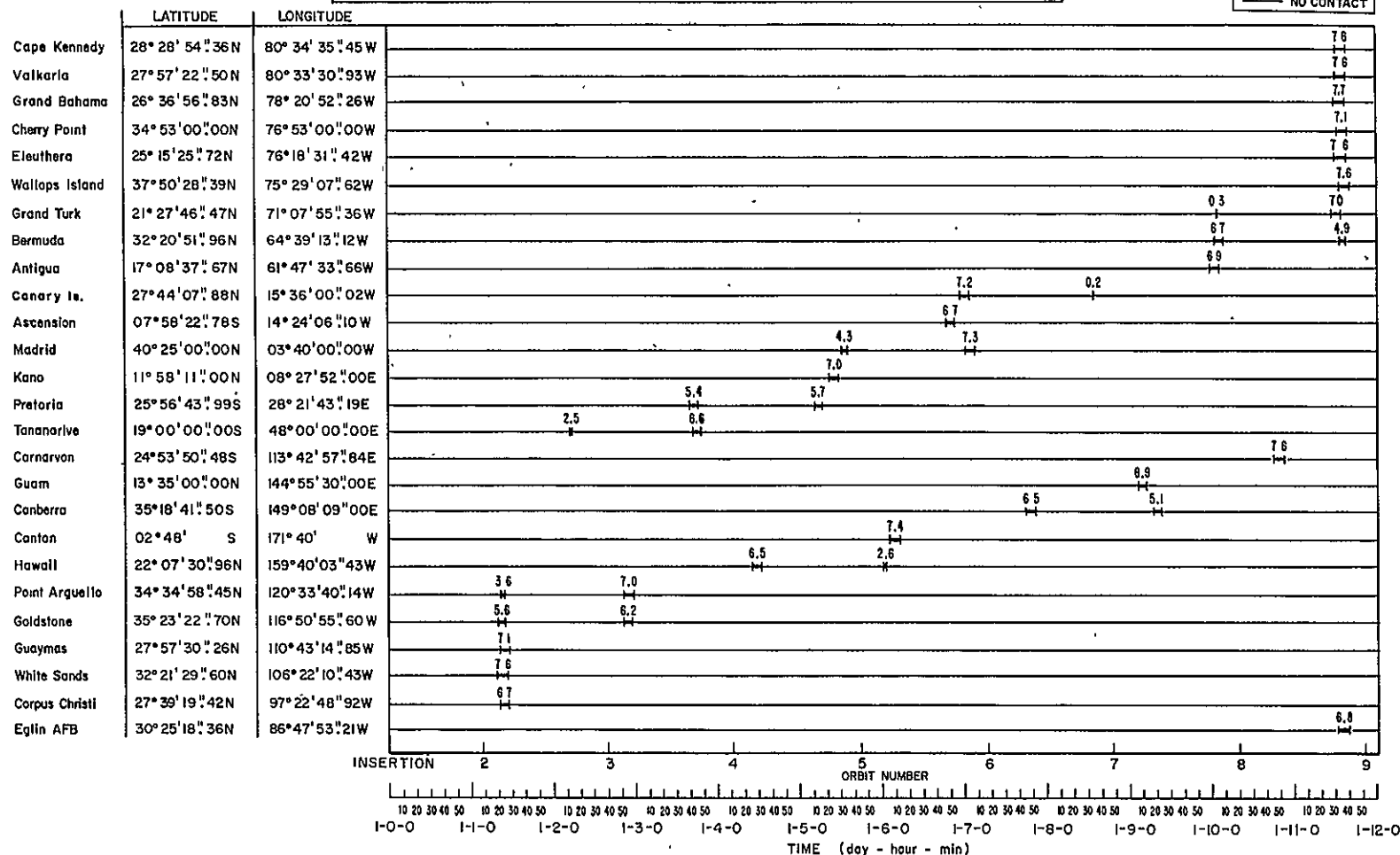


Figure 15—Apollo Extension System Station Coverage for Polar Orbits,  $i = 90^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 to 9, First Day



# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR POLAR ORBITS

$i = 90^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 1 to 9, FIRST DAY

### ORBITAL PARAMETERS AT INSERTION

OSCILLATING ELEMENTS		POSITION AND VELOCITY	
T = 26 MAY 1966 0 <sup>h</sup> 0 <sup>m</sup> 0 <sup>s</sup>		X = -3392 26740 nm	Y = -6282 47337 km
a = 3647 8505 nm or 6755 892 km		Y = 1296 48080 nm	Y = 2401 08264 km
e = 0.0010739		Z = -299 84613 nm	Z = -555 31504 km
i = 89.999999°			
$\Omega = 339.083786^\circ$		X = 0 31913894 nm/sec	X = 0 59104532 km/sec
$\omega = 184.719851^\circ$		Y = -0 12197079 nm/sec	Y = -0 22588991 km/sec
M = 0.000148°		Z = -4 13791390 nm/sec	Z = -7 66341662 km/sec
			ALTITUDE = 200 nm or 370.4 km
			VELOCITY = 25,214.5 ft/sec
			LATITUDE = -4.7499°
			LONGITUDE = -84.0337°
			INCLINATION = 90°

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

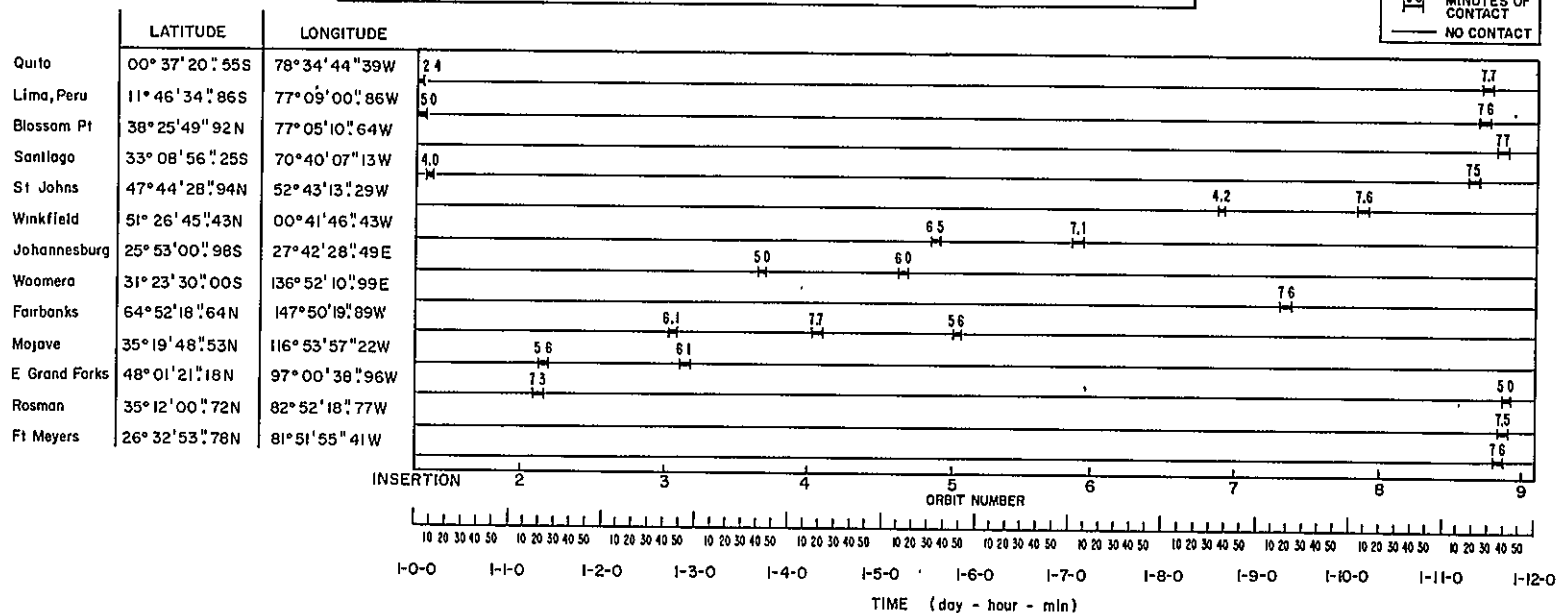


Figure 15 (Continued)—Apollo Extension System Station Coverage for Polar Orbits,  $i = 90^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 to 9, First Day

# **APOLLO EXTENSION SYSTEM** **POLAR ORBITS, $i = 81.5^\circ$ , $H = 200$ nm, $\epsilon \geq 5^\circ$** **ORBITS 1 through 15, FIRST DAY**

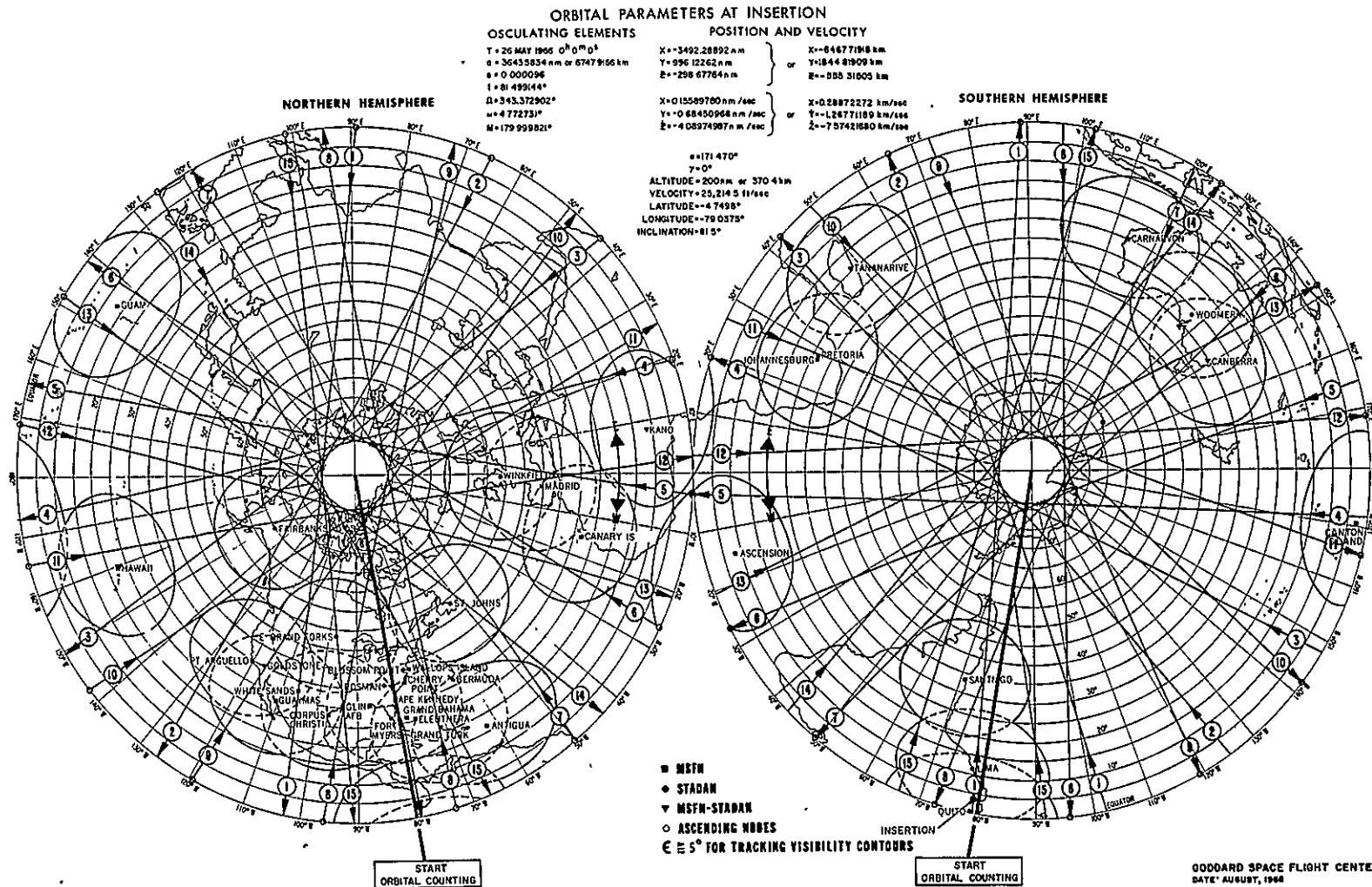


Figure 16-Apollo Extension System Polar Orbits,  $i = 81.5^\circ$ ,  $H = 200$  nm,  
 $\epsilon \geq 5^\circ$ , Orbits 1 through 15, First Day


# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR POLAR ORBITS

$i = 81.5^\circ$ ,  $H = 200\text{nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 1 to 8, FIRST DAY

### ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS	POSITION AND VELOCITY		
T = 26 MAY 1966 0 <sup>h</sup> 0 <sup>m</sup> 0 <sup>s</sup>	X = -3492 28892 nm	X = -6467 71918 km	$\alpha = 171.470^\circ$
a = 3643 5834 nm or 6747 9166 km	Y = 996 12262 nm	or Y = 1844 81909 km	$\gamma = 0^\circ$
e = 0.000096	Z = -298.67764 nm	Z = -555 31505 km	ALTITUDE = 200nm or 370.4 km
I = 81.499144°			VELOCITY = 25,214.5 ft/sec
$\Omega = 343.372902^\circ$	X = 0.15589780 nm/sec	X = 0.28872272 km/sec	LATITUDE = -4.7498°
$\omega = 4.772731^\circ$	Y = -0.68450966 nm/sec	or Y = -1.26771189 km/sec	LONGITUDE = -79.0375°
M = 179.999821°	Z = -4.08974987 nm/sec	Z = -7.57421680 km/sec	INCLINATION = 81.5°

KEY  
 MINUTES OF CONTACT  
 --- NO CONTACT

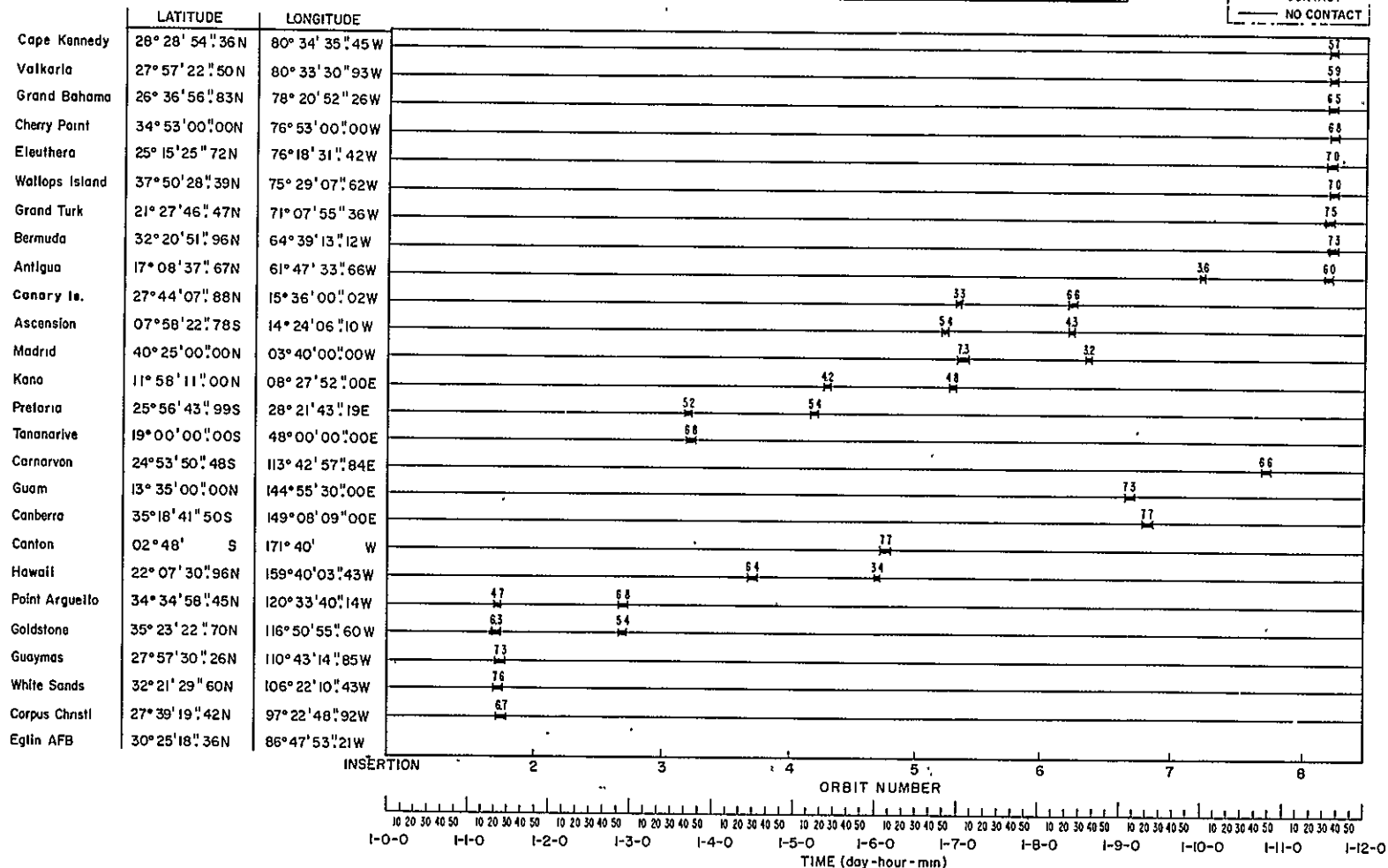


Figure 17--Apollo Extension System Station Coverage for Polar Orbits,  $i = 81.5^\circ$ ,  $H = 200\text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 to 8, First Day

# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR POLAR ORBITS

$i = 81.5^\circ$ ,  $H = 200\text{nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 1 to 8, FIRST DAY

### ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS	POSITION AND VELOCITY		
T = 26 MAY 1966 0 <sup>h</sup> 0 <sup>m</sup> 0 <sup>s</sup>	X = -3492 28892 nm	X = -6467 71918 km	$\alpha = 171.470^\circ$
a = 3643 5834 nm or 6747 9166 km	Y = 996.12262 nm	or Y = 1844 81909 km	$\gamma = 0^\circ$
e = 0.000096	Z = -298 67764 nm	Z = -555 31505 km	ALTITUDE = 200nm or 370.4 km
I = 81.499144°			VELOCITY = 25,214.5 ft/sec
$\Omega = 343.372902^\circ$	X = 0.15589780 nm/sec	X = 0.28872272 km/sec	LATITUDE = -4.7498°
$\omega = 4.772731^\circ$	Y = -0.68450966 nm/sec	or Y = -1.26771189 km/sec	LONGITUDE = -79.0375°
M = 179.999821°	Z = -0.08974987 nm/sec	Z = -757421680 km/sec	INCLINATION = 81.5°

KEY	MINUTES OF CONTACT
1.0	1.0
—	NO CONTACT

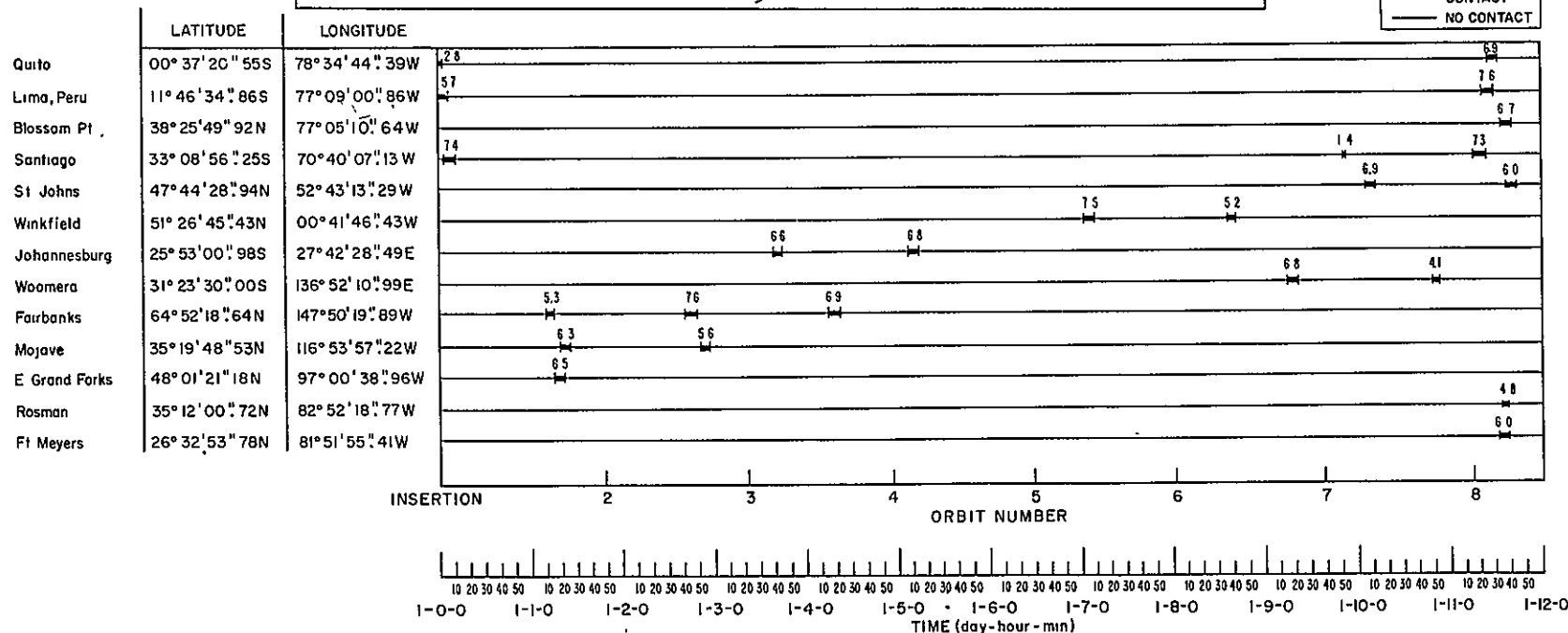


Figure 17 (Continued)—Apollo Extension System Station Coverage for Polar Orbits,  $i = 81.5^\circ$ ,  $H = 200\text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 to 8, First Day

# **APOLLO EXTENSION SYSTEM** **EARTH ORBITS, $i=50.3^\circ$ , $H=200$ nm, $\epsilon \geq 5^\circ$** **ORBITS 1 through 7, FIRST DAY**

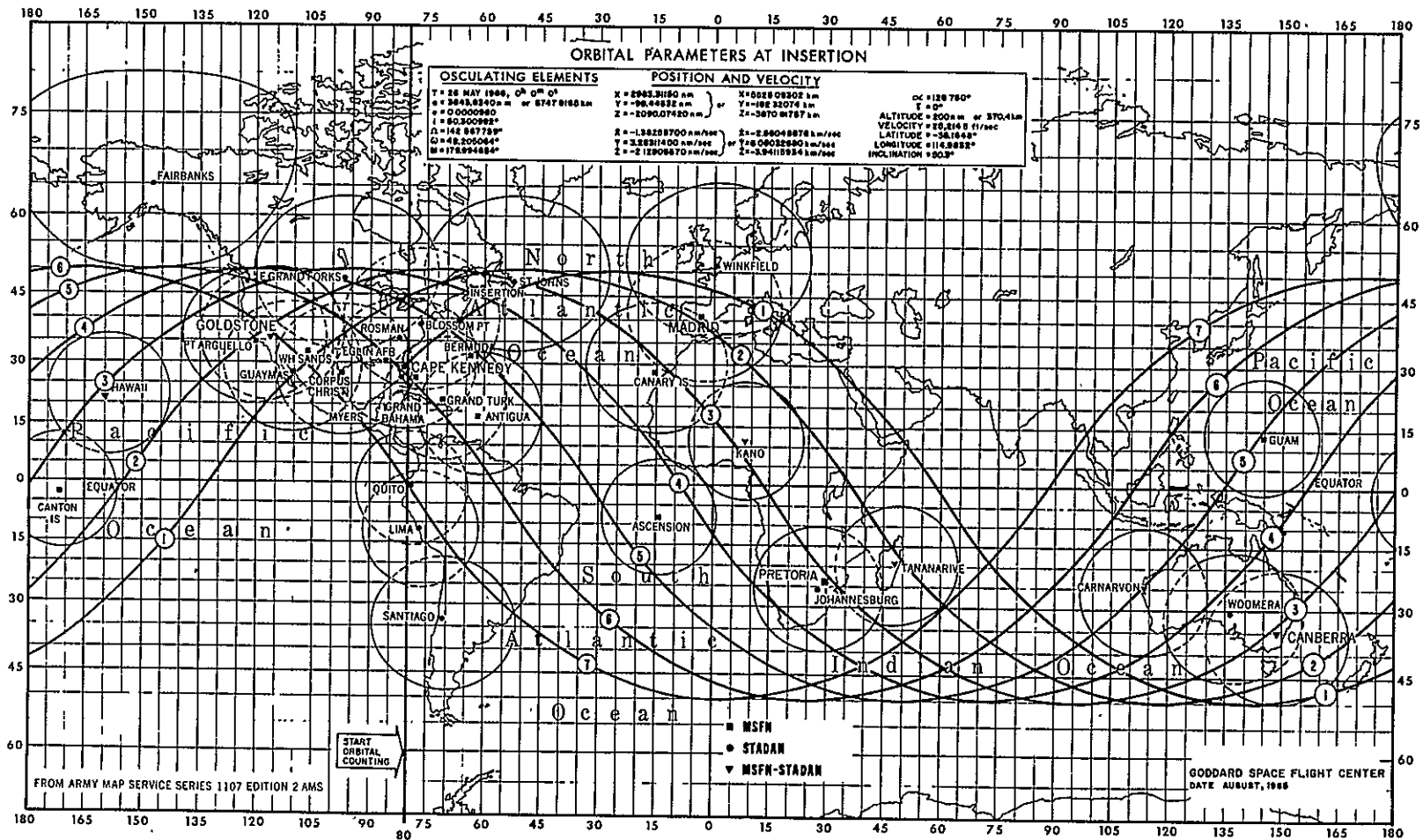


Figure 18-Apollo Extension System Earth Orbits,  $i = 50.3^\circ$ ,  $H = 200$  nm,  $\epsilon \geq 5^\circ$ , Orbits 1 through 7, First Day



# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR EARTH ORBITS

$i = 50.3^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 1 to 8, FIRST DAY

### ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS		POSITION AND VELOCITY	
T = 26 MAY 1968, 0h 0m 0s	X = 2983 31150 nm	X = 5525 09502 km	$\alpha = 128.760^\circ$
a = 3645.8540 nm or 6747 9165 km	Y = -98.44532 nm	Y = -102 32074 km	$\gamma = 0^\circ$
e = 0.0000960	Z = -2090 07420 nm	Z = -3870 81767 km	ALTITUDE = 200 nm or 370 4 km
i = 50.300992°			VELOCITY = 25,214 5 ft/sec
$\Omega = 142.557759^\circ$	X = -1.38255700 nm/sec	X = -2.56048876 km/sec	LATITUDE = -35.1648°
$\dot{\Omega} = 48.205064^\circ$	Y = 3.28311400 nm/sec	Y = 6.08032680 km/sec	LONGITUDE = 114.9832°
M = 179994854°	Z = -2.12005570 nm/sec	Z = -3.94115934 km/sec	INCLINATION = 50.3°

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

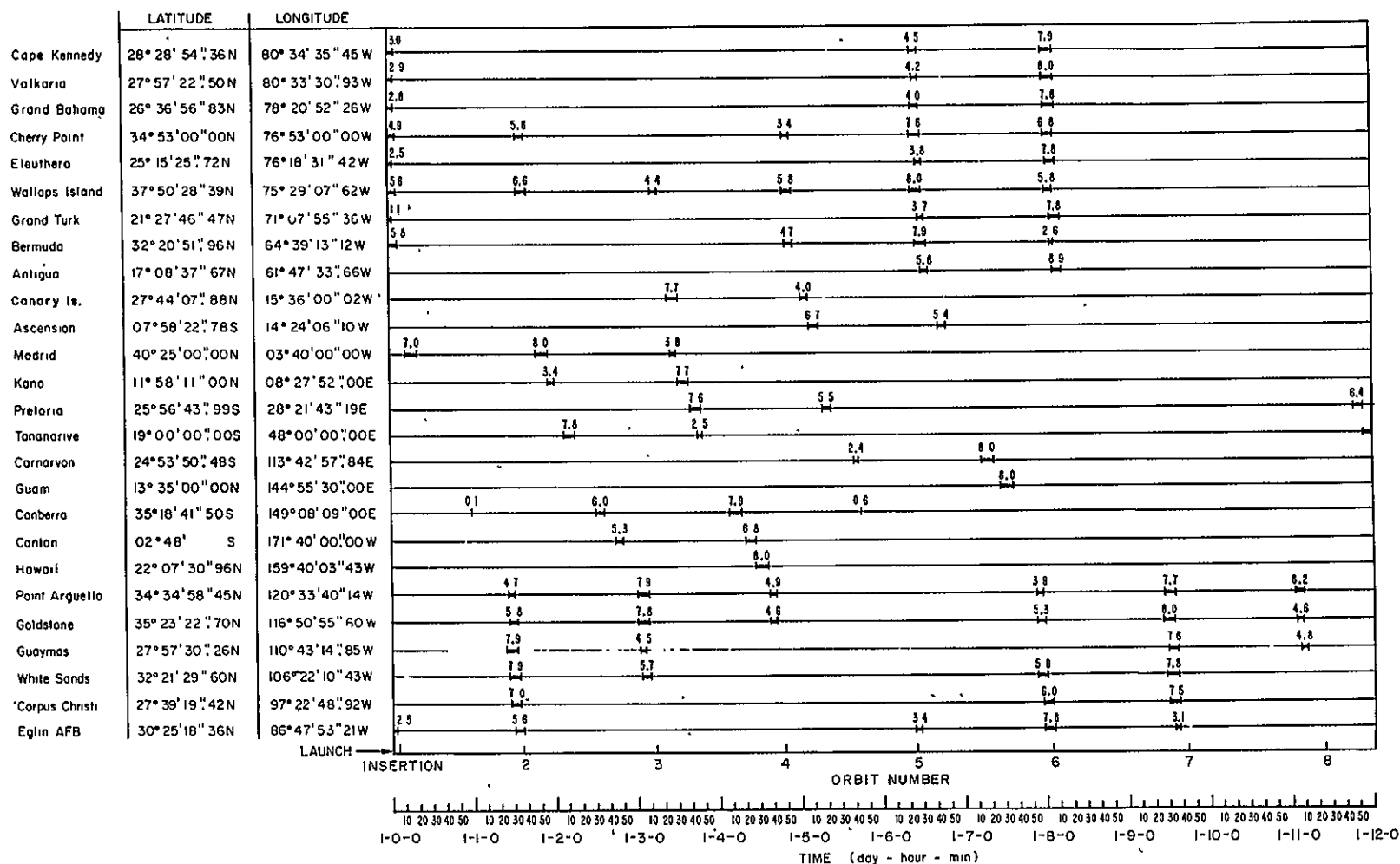




Figure 19—Apollo Extension System Station Coverage for Earth Orbits,  $i = 50.3^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 to 8, First Day

# APOLLO EXTENSION SYSTEM

STATION COVERAGE FOR EARTH ORBITS  
 $i = 50.3^\circ$ ,  $H = 200\text{nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 8 to 15, FIRST DAY

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

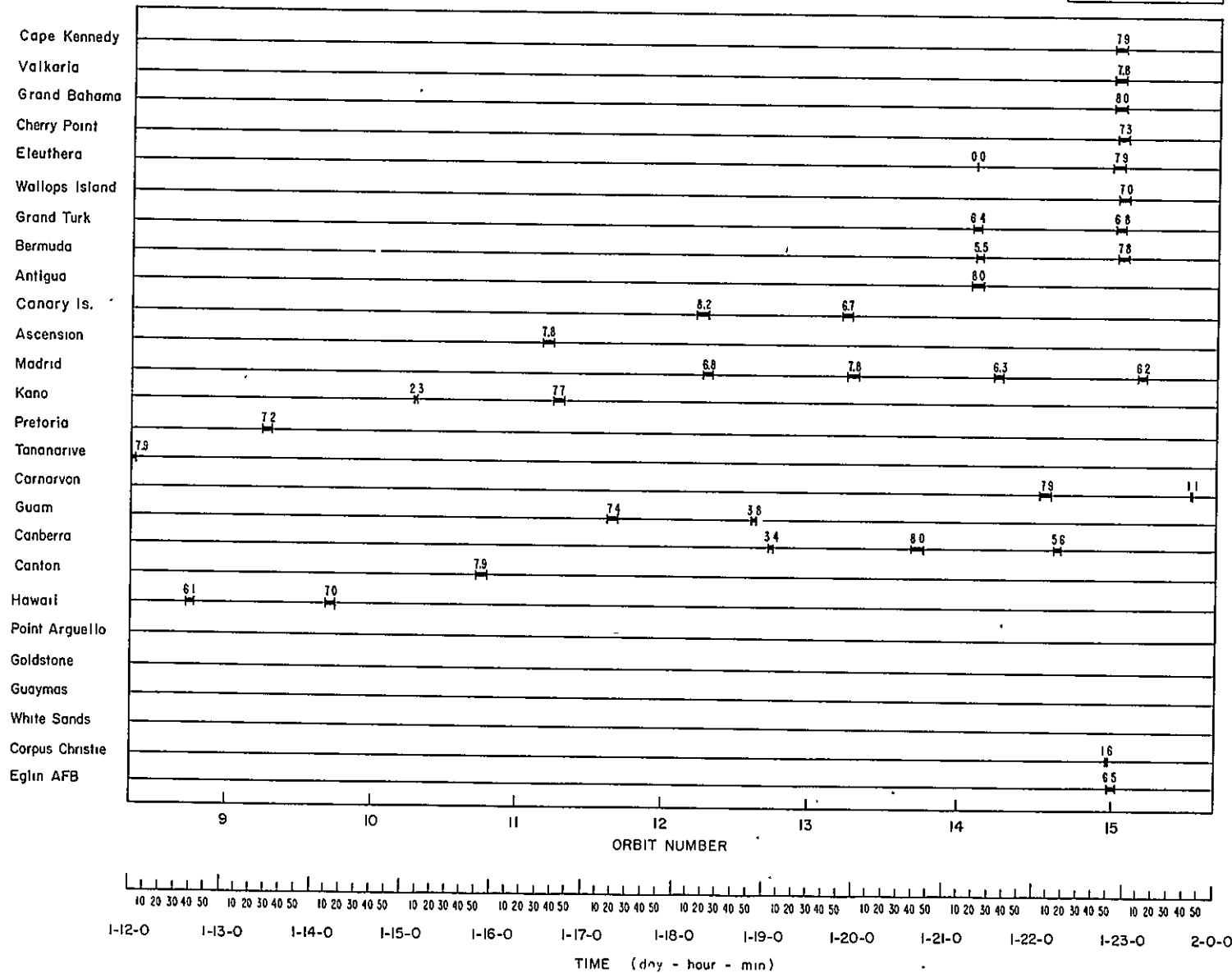


Figure 19 (Continued)—Apollo Extension System Station Coverage for Earth Orbits,  $i = 50.3^\circ$ ,  $H = 200\text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 8 to 15, First Day

# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR EARTH ORBITS

$i = 50.3^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 1 to 8, FIRST DAY

ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS		POSITION AND VELOCITY	
T = 26 MAY 1966, 0 <sup>h</sup> 0 <sup>m</sup> 0 <sup>s</sup>		X = 2983 31150 nm	
a = 3843 8540 nm or 6747 9165 km		Y = -98 44832 nm	
e = 0.0000980		Z = -2090 07420 nm	
i = 50.300992°		or	
$\Omega = 142.587759^\circ$		X = -2 560 48876 km/sec	
$\dot{\Omega} = 48.205064^\circ$		Y = 3.28311400 nm/sec	
M = 179 994634°		Z = -2 12605570 nm/sec	
		or	
		X = 5526.09802 km	
		Y = -162.32074 km	
		Z = -3870 81787 km	
		or	
		ALTITUDE = 200 nm or 370.4 km	
		VELOCITY = 26,214.5 ft/sec	
		LATITUDE = -35.1648°	
		LONGITUDE = 114.9832°	
		INCLINATION = 50.3°	

KEY	
	MINUTES OF CONTACT
	NO CONTACT

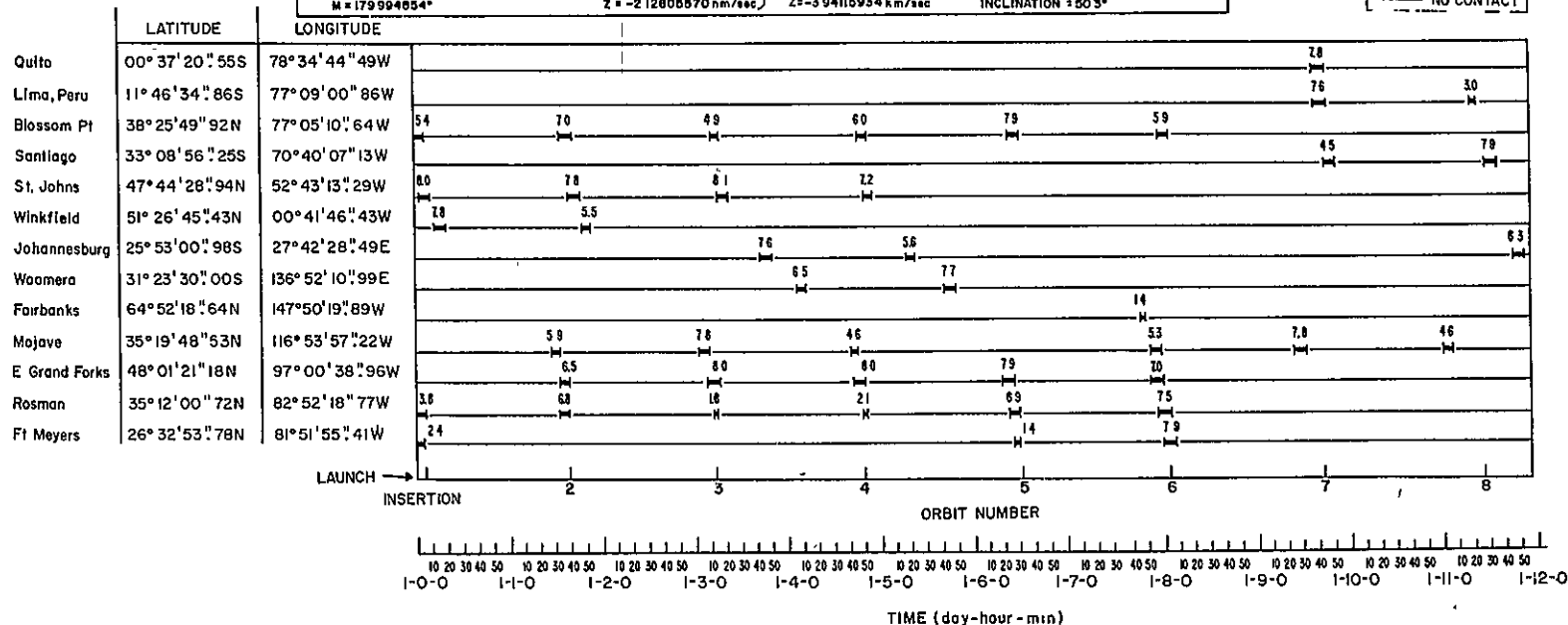




Figure 19 (Continued)–Apollo Extension System Station Coverage for Earth Orbits,  $i = 50.3^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 to 8, First Day

# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR EARTH ORBITS

$i = 50.3^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 8 to 15, FIRST DAY

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

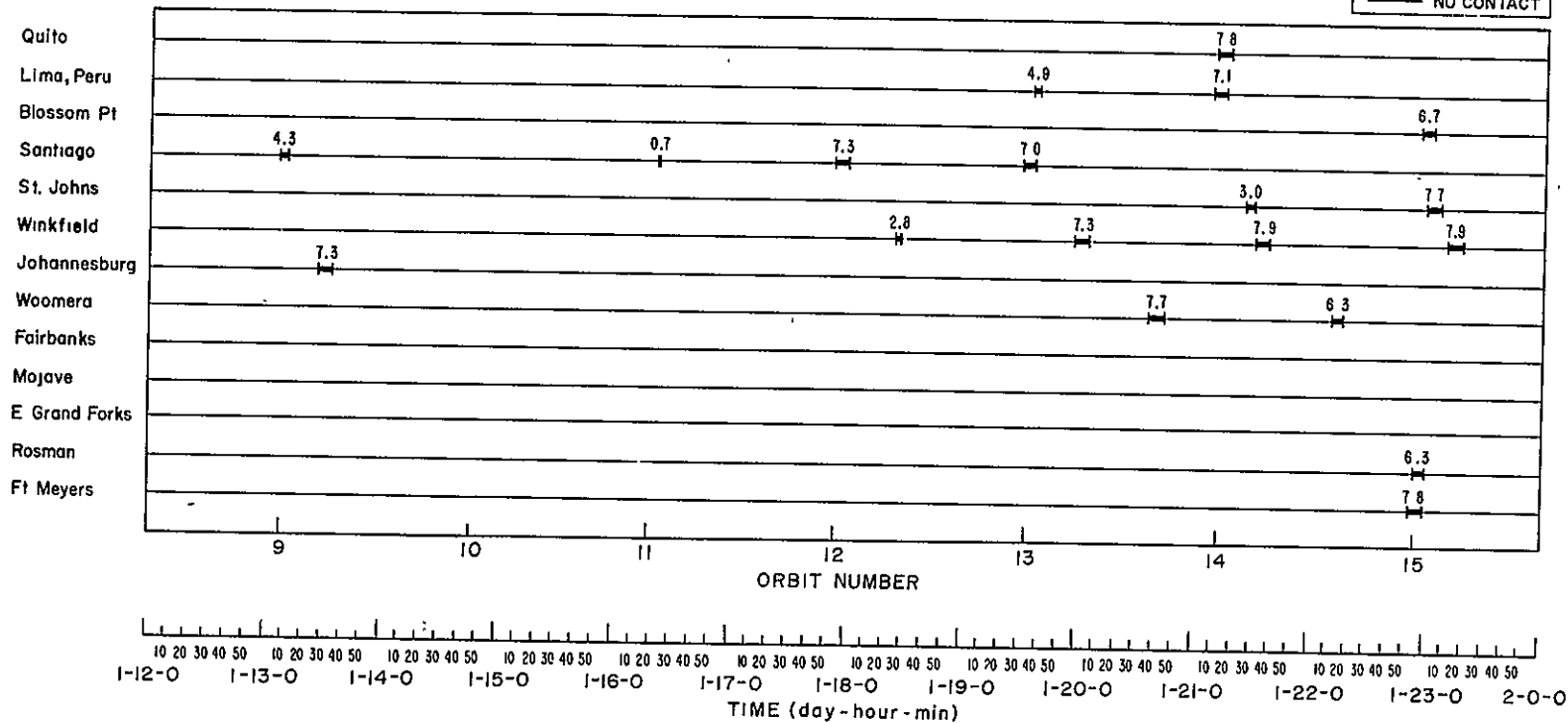


Figure 19 (Continued)—Apollo Extension System Station Coverage for Earth Orbits,  $i = 50.3^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 8 to 15, First Day

# **APOLLO EXTENSION SYSTEM** **LOW INCLINATION ORBITS $i=28.5^\circ$ , $H=200\text{ nm}$ , $\epsilon \geq 5^\circ$** **ORBITS 1 through 8, FIRST DAY**

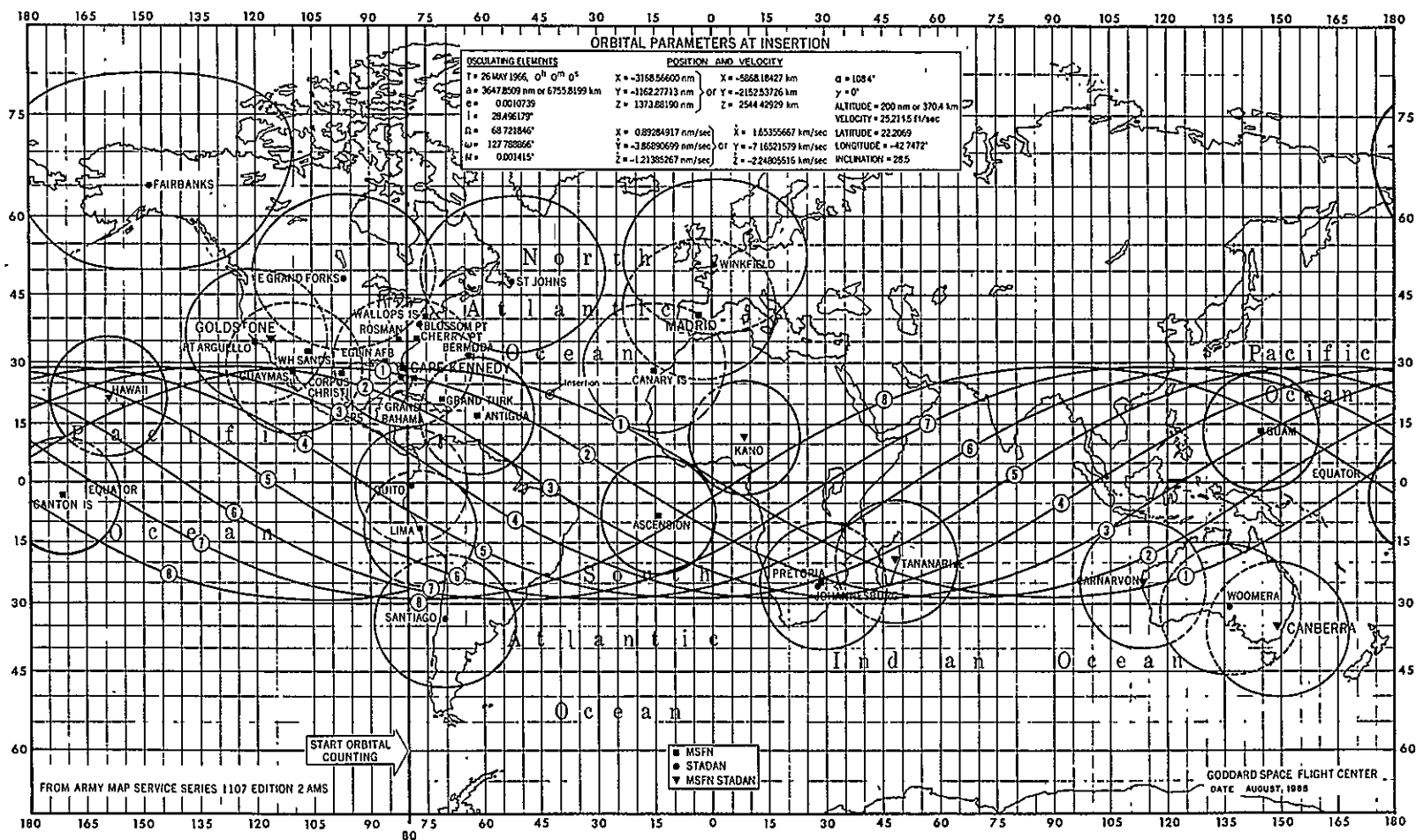


Figure 20—Apollo Extension System Low Inclination Orbits,  $i = 28.5^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 through 8, First Day

# **APOLLO EXTENSION SYSTEM** **STATION COVERAGE FOR LOW INCLINATION ORBITS** $i = 28.5^\circ$ , $H = 200 \text{ nm}$ , $\epsilon \geq 5^\circ$ , ORBITS 1 to 8, FIRST DAY

## ORBITAL PARAMETERS AT INSERTION

OSCILLATING ELEMENTS			POSITION AND VELOCITY		
$T = 26.959 \text{ days}$	$\Omega = 289.6179^\circ$	$\omega = 68.721848^\circ$	$X = -3168.36600 \text{ nm}$	$Y = -1162.27713 \text{ nm}$	$Z = 1373.88190 \text{ nm}$
$a = 3647.2502 \text{ nm}$	$e = 0.0010739$	$i = 28.496179^\circ$	$\dot{X} = 0.89284917 \text{ nm/sec}$	$\dot{Y} = -3.86830639 \text{ nm/sec}$	$\dot{Z} = -1.21385267 \text{ nm/sec}$
$\alpha = 108.4^\circ$	$\gamma = 0^\circ$	$\text{ALTITUDE} = 200 \text{ nm or } 370.4 \text{ km}$	$\dot{X} = 1.63355667 \text{ km/sec}$	$\dot{Y} = -7.16521579 \text{ km/sec}$	$\dot{Z} = -2.24005516 \text{ km/sec}$
$\text{VELOCITY} = 25,214.5 \text{ ft/sec}$	$\text{LATITUDE} = 22.2069^\circ$	$\text{LONGITUDE} = -42.7472^\circ$	$\text{INCLINATION} = 28.5^\circ$		

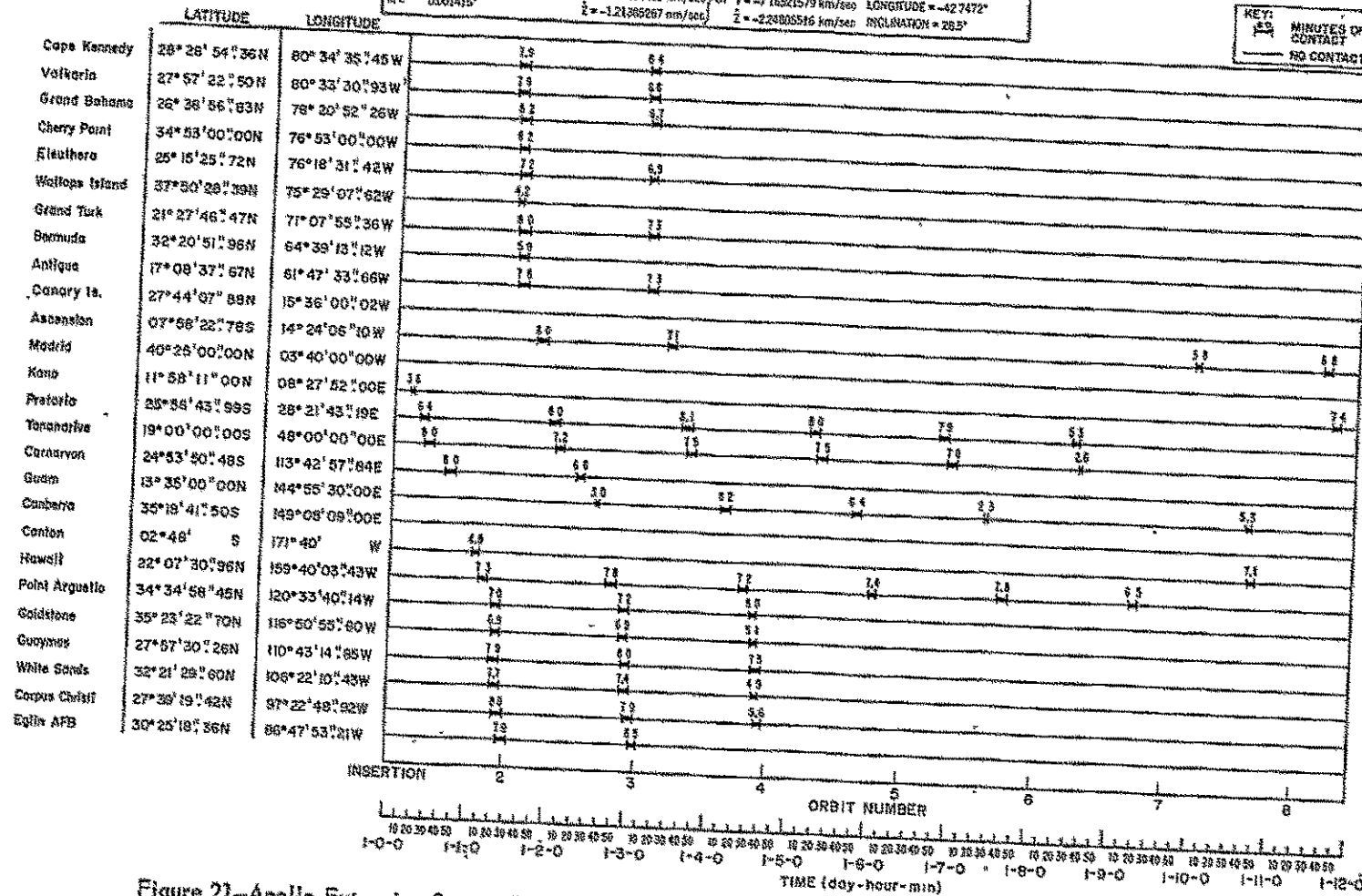




Figure 21—Apollo Extension System Station Coverage for Low Inclination Orbits,  $i = 28.5^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 to 8, First Day

# **APOLLO EXTENSION SYSTEM** **STATION COVERAGE FOR LOW INCLINATION ORBITS** $i=28.5^\circ$ , $H=200\text{nm}$ , $\epsilon \geq 5^\circ$ , ORBITS 8 to 15, FIRST DAY

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

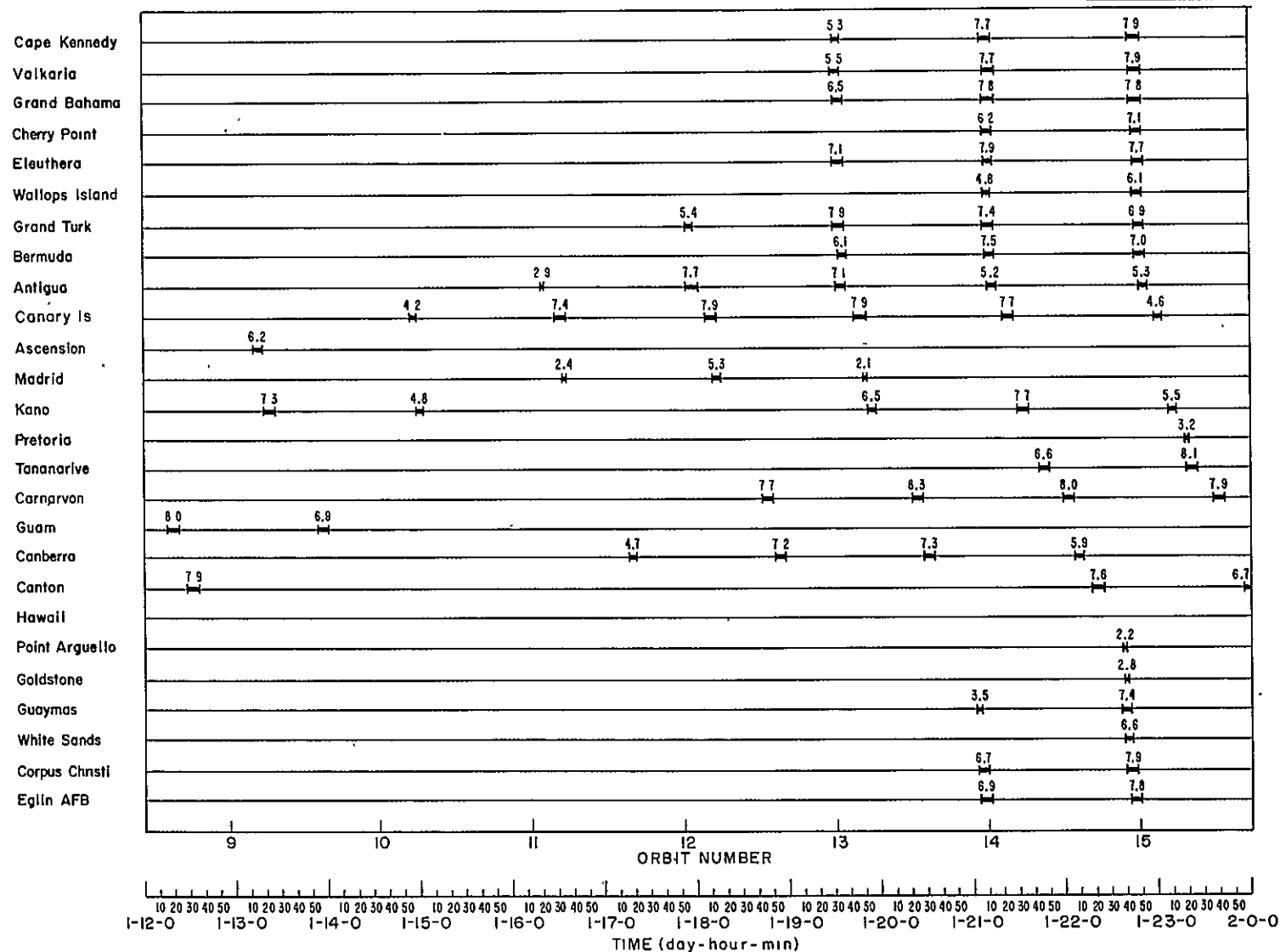




Figure 21 (Continued)—Apollo Extension System Station Coverage for Low Inclination Orbits,  $i = 28.5^\circ$ ,  $H = 200\text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 8 to 15, First Day

# **APOLLO EXTENSION SYSTEM** **STATION COVERAGE FOR LOW INCLINATION ORBITS** $i=28.5^\circ$ , $H=200\text{nm}$ , $\epsilon \geq 5^\circ$ , ORBITS 1 to 8, FIRST DAY

## ORBITAL PARAMETERS AT INSERTION

OSCULATING ELEMENTS		POSITION AND VELOCITY	
$T = 26 \text{ MAY } 1966, 0^h 0^m 0^s$	$X = -3168.56600 \text{ nm}$	$X = -5868.18427 \text{ km}$	$\alpha = 108.4^\circ$
$a = 3647.8509 \text{ nm or } 6755.8199 \text{ km}$	$Y = -1162.27713 \text{ nm}$	$Y = -2152.53726 \text{ km}$	$\gamma = 0^\circ$
$e = 0.0010739$	$Z = 1373.88190 \text{ nm}$	$Z = 2544.42929 \text{ km}$	ALTITUDE = 200 nm or 370.4 km
$i = 28.496179^\circ$			VELOCITY = 25,214.5 ft/sec
$\Omega = 68.721846^\circ$	$\dot{X} = 0.89284917 \text{ nm/sec}$	$\dot{X} = 1.65355667 \text{ km/sec}$	LATITUDE = 22.2069°
$\omega = 127.788866^\circ$	$\dot{Y} = -3.86890699 \text{ nm/sec}$	$\dot{Y} = -7.16521579 \text{ km/sec}$	LONGITUDE = -42.7472°
$M = 0.001415^\circ$	$\dot{Z} = -1.21385267 \text{ nm/sec}$	$\dot{Z} = -2.24805516 \text{ km/sec}$	INCLINATION = 28.5°

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

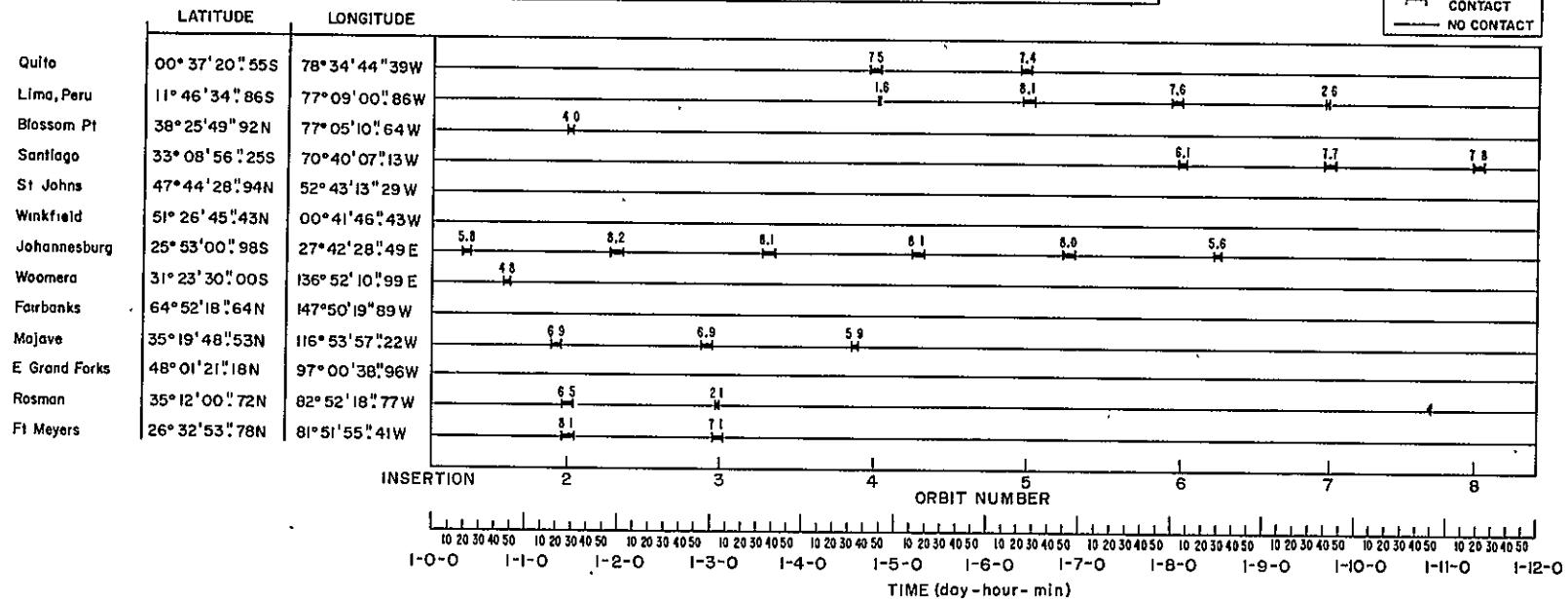


Figure 21 (Continued)–Apollo Extension System Station Coverage for Low Inclination Orbits,  $i = 28.5^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 1 to 8, First Day

# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR LOW INCLINATION ORBITS

$i=28.5^\circ$ ,  $H=200\text{nm}$ ,  $\epsilon \geq 5^\circ$ , ORBITS 8 to 15, FIRST DAY

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

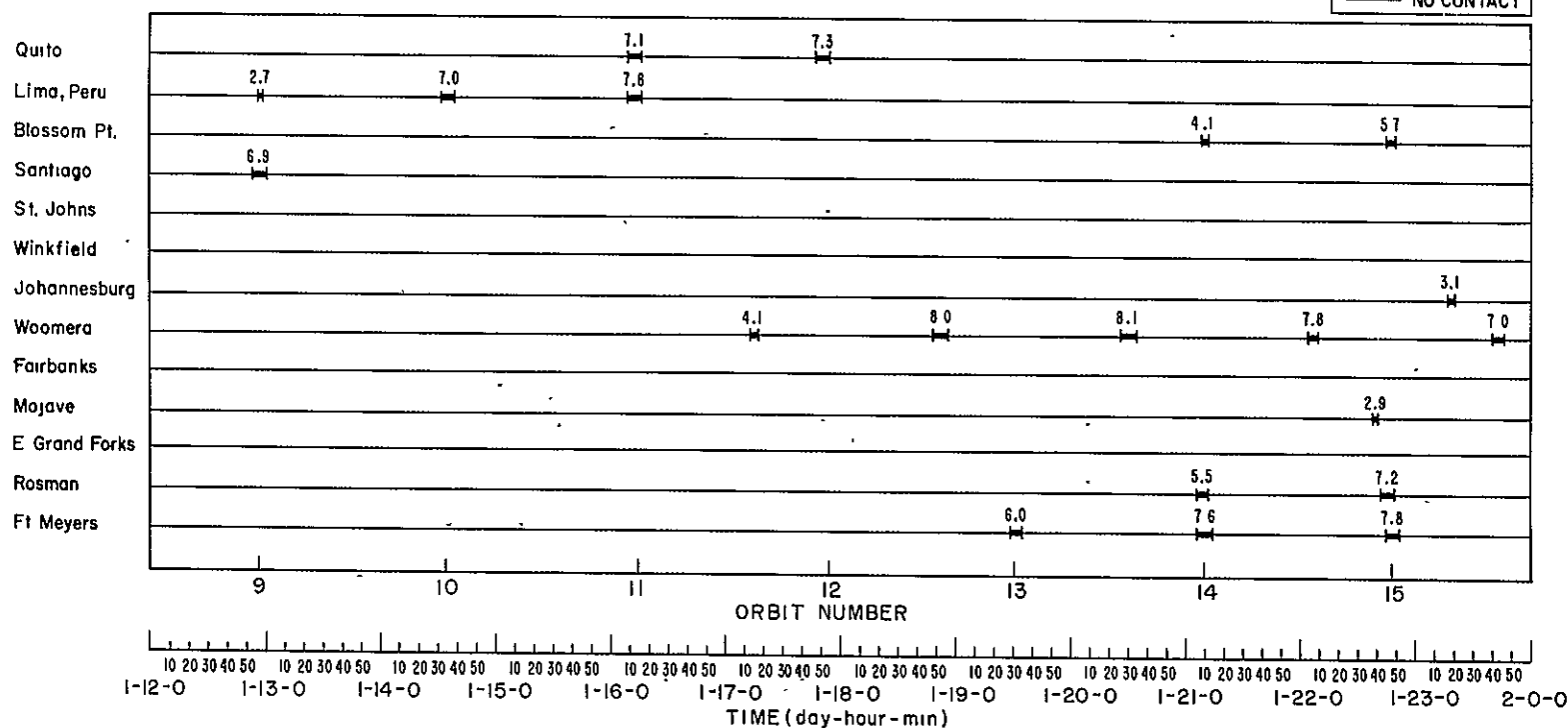


Figure 21 (Continued)—Apollo Extension System Station Coverage for Low Inclination Orbits,  $i = 28.5^\circ$ ,  $H = 200 \text{ nm}$ ,  $\epsilon \geq 5^\circ$ , Orbits 8 to 15, First Day

# APOLLO EXTENSION SYSTEM SYNCHRONOUS ORBIT ( TYPE 2 )

$\epsilon \geq 5^\circ$

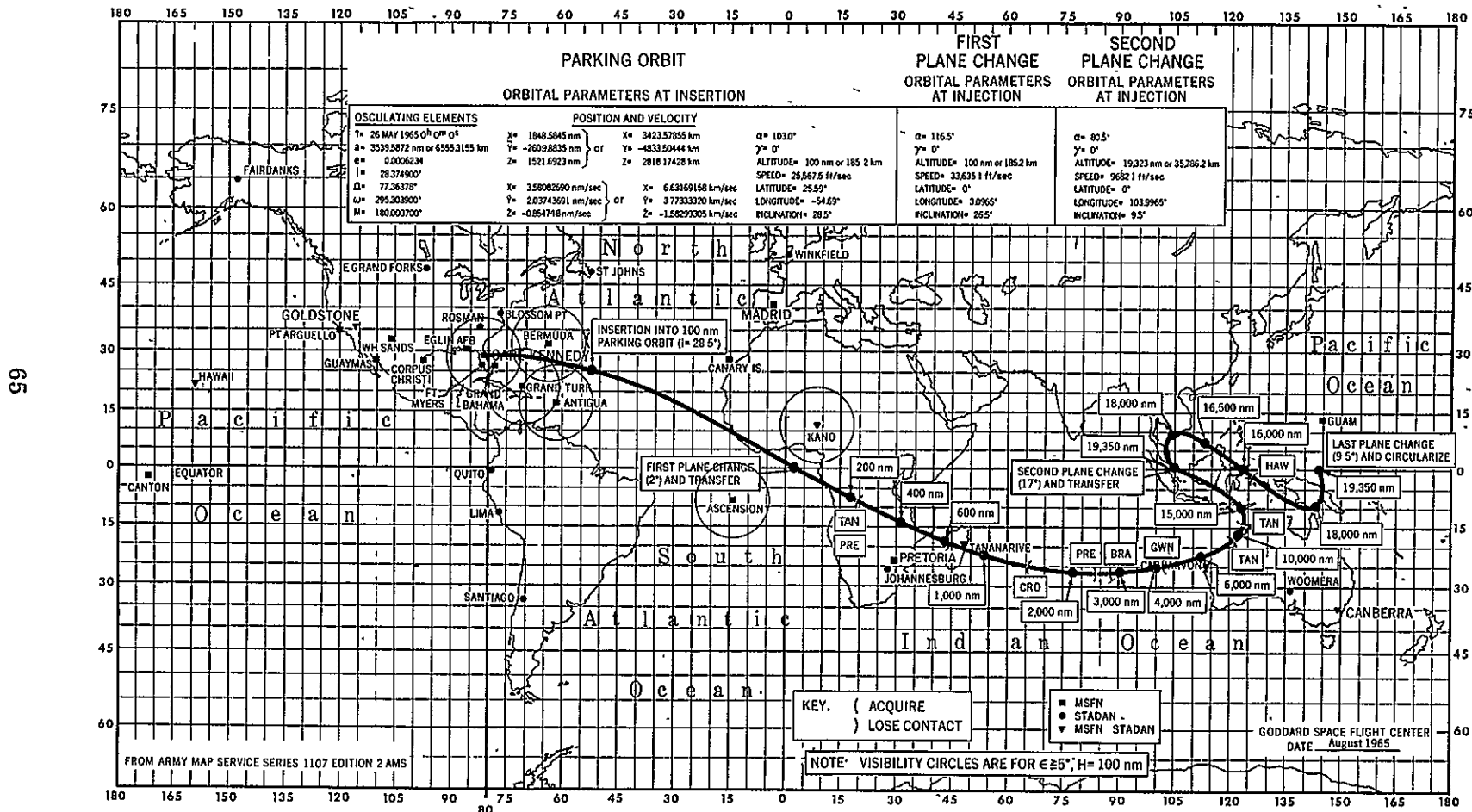


Figure 22-Apollo Extension System Synchronous Orbit (Type 2),  $\epsilon \geq 5^\circ$

# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR SYNCHRONOUS ORBIT (TYPE 2)

$\epsilon \geq 5^\circ$

PARKING ORBIT

FIRST PLANE CHANGE

SECOND PLANE CHANGE

### ORBITAL PARAMETERS AT INSERTION

### ORBITAL PARAMETERS AT INJECTION

### ORBITAL PARAMETERS AT INJECTION

OSCULATING ELEMENTS	POSITION AND VELOCITY				
$T = 26 \text{ MAY } 1965 - 0^h 0^m 0^s$ $a = 3539.5872 \text{ km or } 6559.3195 \text{ km}$ $e = 0.0004254$ $i = 28.374900^\circ$ $\Omega = 77.343780^\circ$ $\omega = 295.303900^\circ$ $M = 180.000700^\circ$	$X = 1848.59450 \text{ km}$ $Y = -2603.88350 \text{ km}$ $Z = 1021.69230 \text{ km}$ $\dot{X} = 3.58062690 \text{ km/sec}$ $\dot{Y} = 2.03743691 \text{ km/sec}$ $\dot{Z} = -0.85474784 \text{ km/sec}$	$X = 5423.97855 \text{ km}$ $Y = -4833.50444 \text{ km}$ $Z = 2818.17428 \text{ km}$ $\dot{X} = 6.63169158 \text{ km/sec}$ $\dot{Y} = 3.77333320 \text{ km/sec}$ $\dot{Z} = -1.08299305 \text{ km/sec}$	$\alpha = 103.0^\circ$ $\gamma = 0^\circ$ $\text{ALTITUDE} = 100 \text{ nm or } 185.2 \text{ km}$ $\text{VELOCITY} = 25,067.6 \text{ ft/sec}$ $\text{LATITUDE} = 28.59^\circ$ $\text{LONGITUDE} = -04.69^\circ$ $\text{INCLINATION} = 28.5^\circ$	$\alpha = 116.5^\circ$ $\gamma = 0^\circ$ $\text{ALTITUDE} = 100 \text{ nm or } 185.2 \text{ km}$ $\text{VELOCITY} = 35,835.1 \text{ ft/sec}$ $\text{LATITUDE} = 0^\circ$ $\text{LONGITUDE} = -3.0965^\circ$ $\text{INCLINATION} = 28.5^\circ$	$\alpha = 80.5^\circ$ $\gamma = 0^\circ$ $\text{ALTITUDE} = 19,323 \text{ nm or } 35,786.2 \text{ km}$ $\text{VELOCITY} = 9002.1 \text{ ft/sec}$ $\text{LATITUDE} = 0^\circ$ $\text{LONGITUDE} = 103.9965^\circ$ $\text{INCLINATION} = 0.8^\circ$

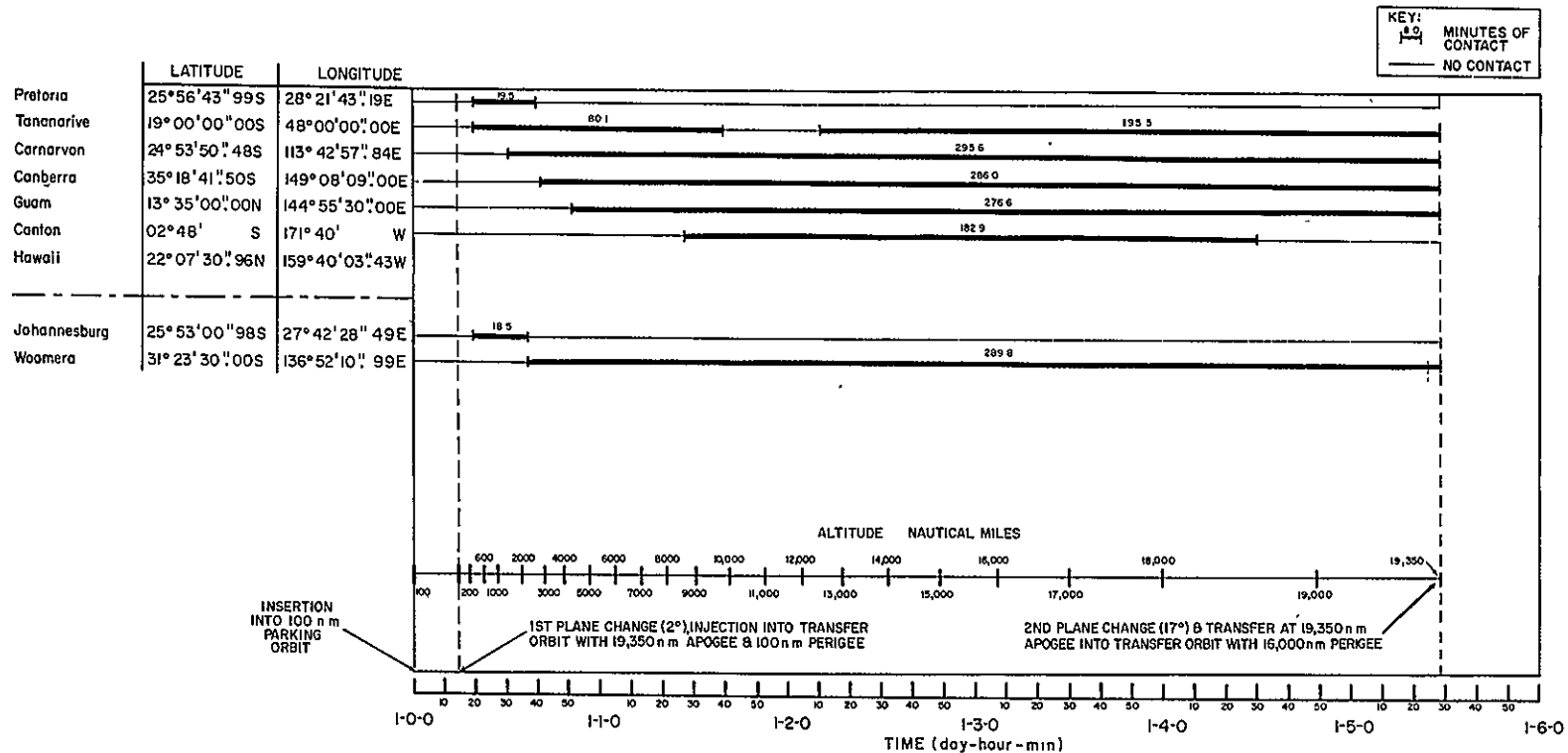




Figure 23-Apollo Extension System Station Coverage for Synchronous Orbit (Type 2),  $\epsilon \geq 5^\circ$

# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR SYNCHRONOUS ORBIT (TYPE 2)

$\epsilon \geq 5^\circ$

KEY:  
 MINUTES OF CONTACT  
 NO CONTACT

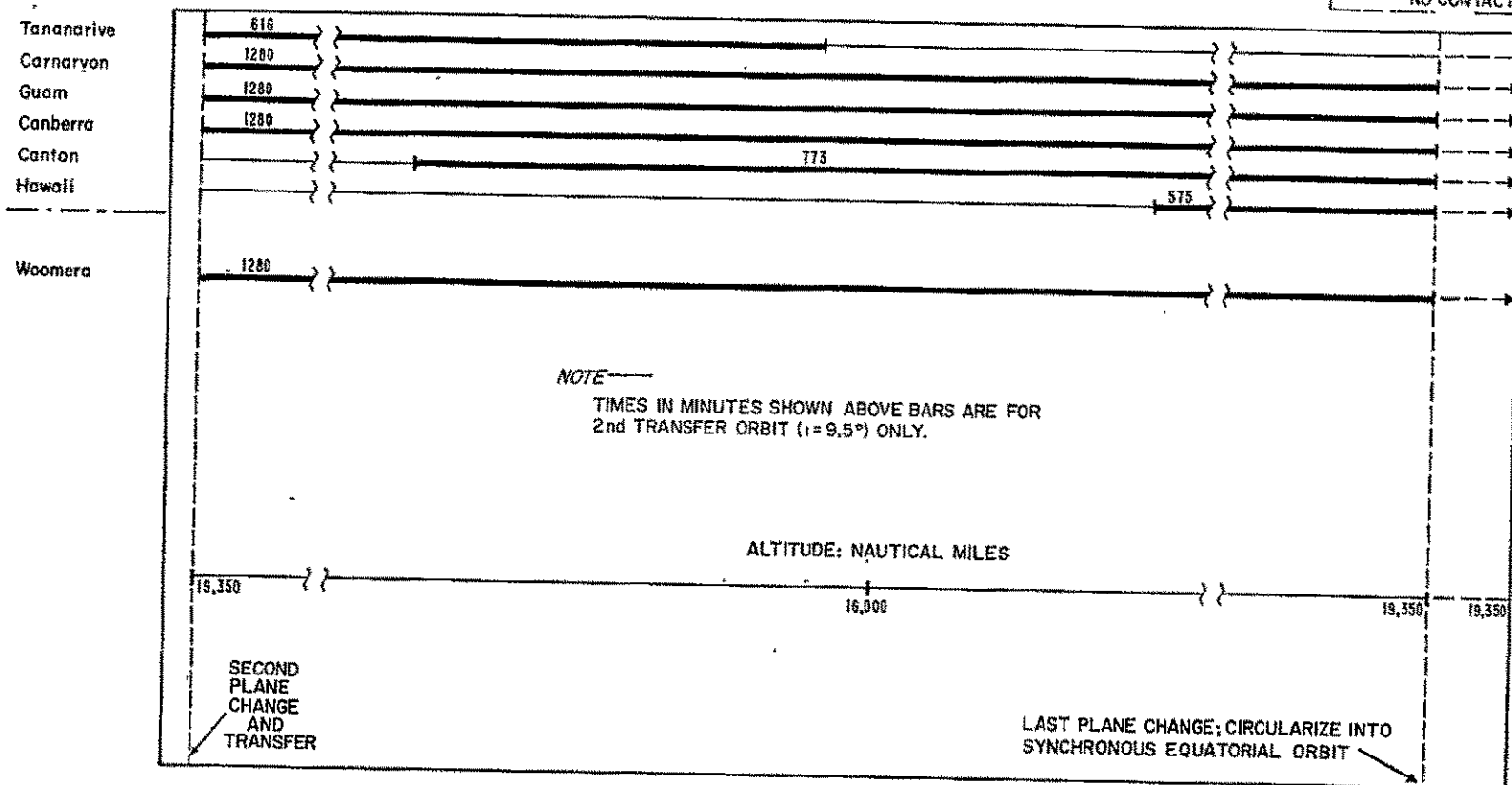


Figure 23 (Continued)—Apollo Extension System Station Coverage for Synchronous Orbit (Type 2),  $\epsilon \geq 5^\circ$

# **APOLLO EXTENSION SYSTEM** **RETURN TRAJECTORY FOR SYNCHRONOUS ORBIT (TYPE 2)** $\epsilon \geq 5^\circ$

68.

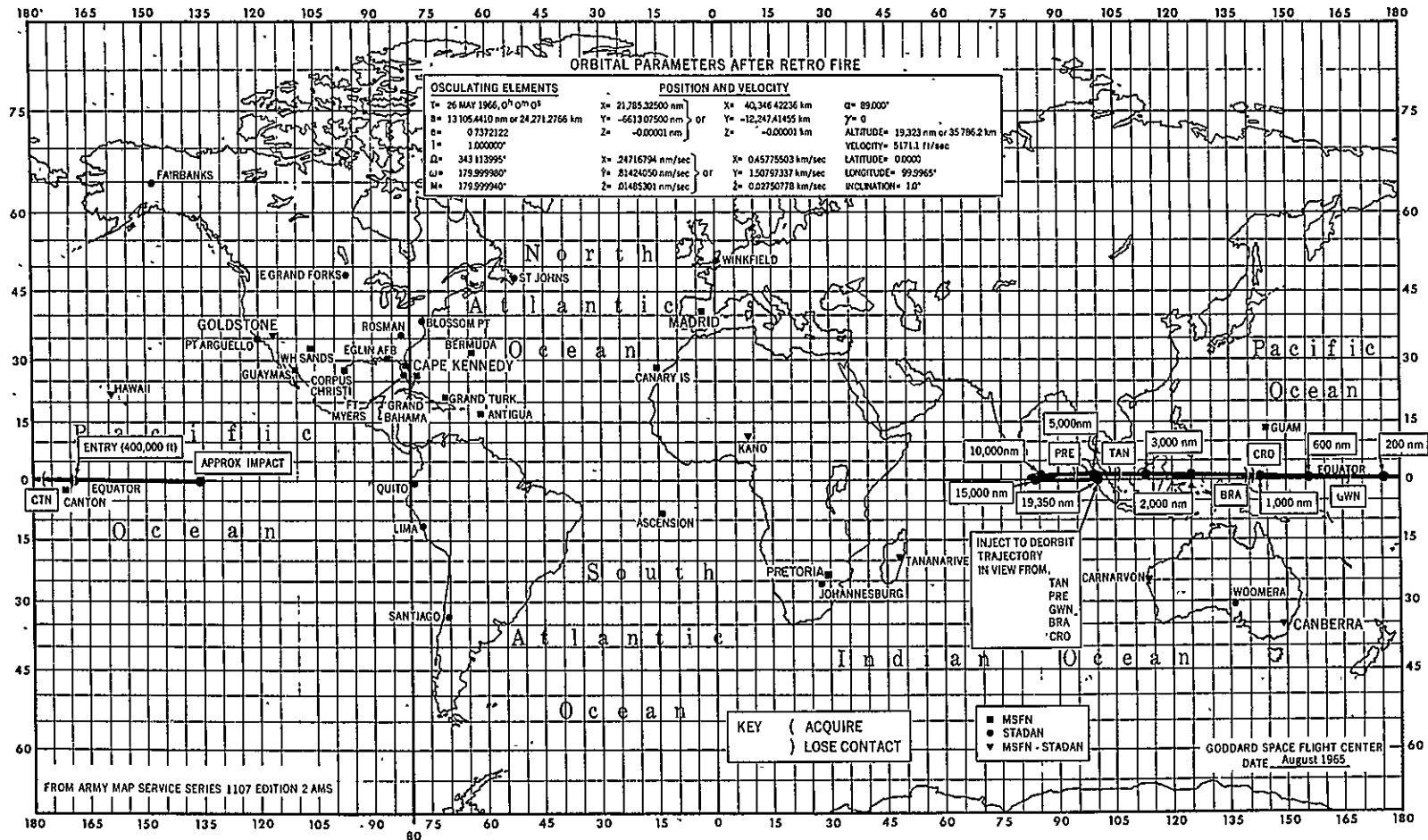


Figure 24-Apollo Extension System Return Trajectory for Synchronous Orbit (Type 2),  $\epsilon \geq 5^\circ$

# APOLLO EXTENSION SYSTEM

## STATION COVERAGE FOR RETURN TRAJECTORY FOR SYNCHORNOUS ORBIT (TYPE 2) : $\epsilon \geq 5^\circ$

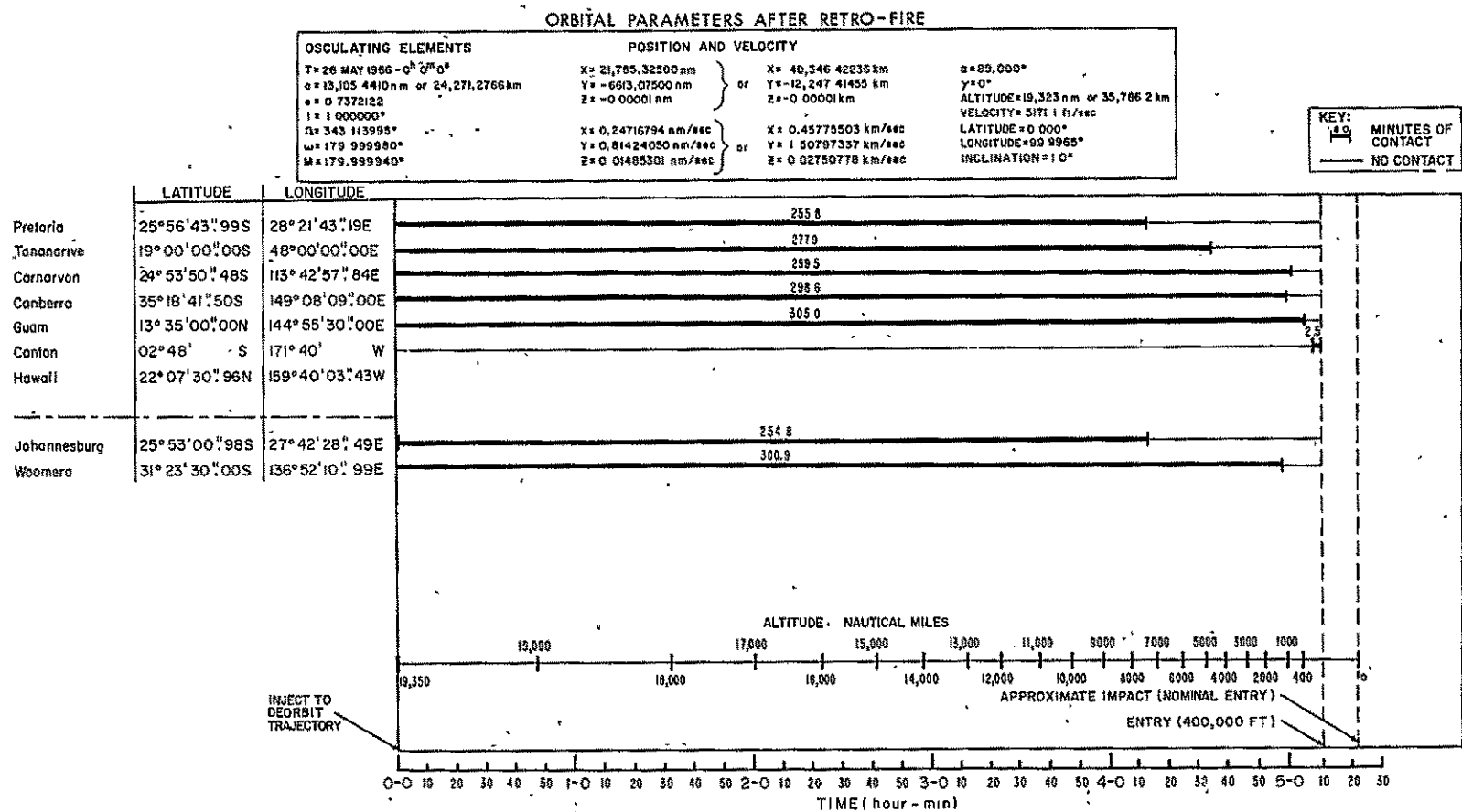


Figure 25—Apollo Extension System Station Coverage for Return Trajectory for Synchronous Orbit (Type 2),  $\epsilon \geq 5^\circ$

# AES LUNAR MISSION EARTH PARKING ORBIT AND TRANSLUNAR TRAJECTORY

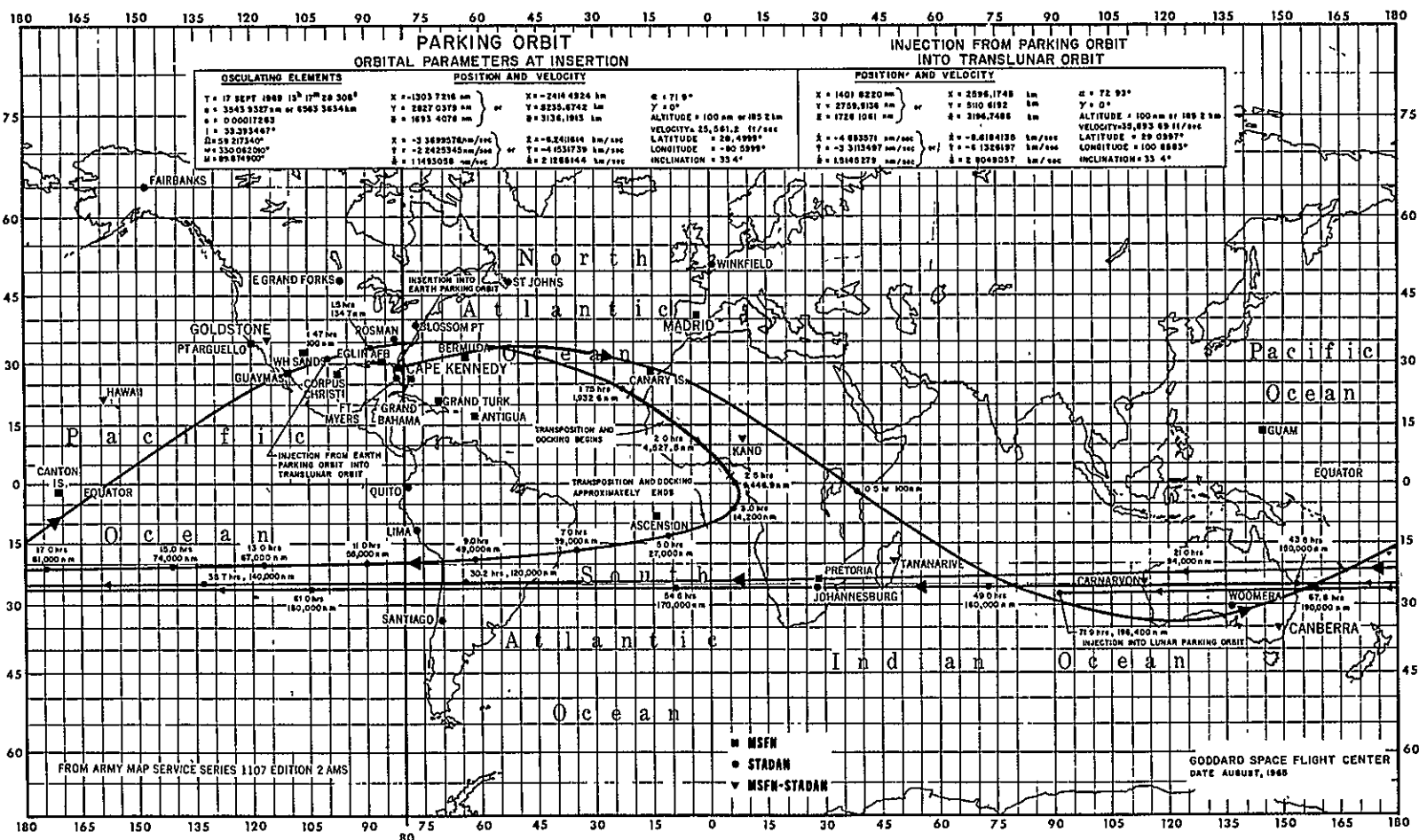


Figure 26—AES Lunar Mission Earth Parking Orbit and Translunar Trajectory

# AES LUNAR MISSION

## STATION COVERAGE FOR EARTH PARKING ORBIT AND TRANSLUNAR TRAJECTORY

$\epsilon \geq 5^\circ$

PARKING ORBIT			INSERTION FROM PARKING ORBIT INTO TRANSLUNAR ORBIT		
OSCULATING ELEMENTS			POSITION AND VELOCITY		
<b>T</b> = 17 SEPT. 1969 13 <sup>h</sup> 17 <sup>m</sup> 28.308 <sup>s</sup> <b>a</b> = 3543 9327 nm or 6563 3634 km <b>e</b> = 0.0001726 <b>i</b> = 33.393467° <b><math>\Omega</math></b> = 59.217340° <b><math>\omega</math></b> = 330.062010° <b>M</b> = 89.874900°			<b>X</b> = -1303.7216 nm <b>Y</b> = 2827.0379 nm <b>Z</b> = 1693.4078 nm <b>X</b> = -3.3699576 nm/sec <b>Y</b> = -2.2425345 nm/sec <b>Z</b> = 1.1493058 nm/sec		
			<b>X</b> = -2414.4924 km <b>Y</b> = 5235.6742 km <b>Z</b> = 3136.1913 km <b>X</b> = -6.2411814 km/sec <b>Y</b> = -4.1531739 km/sec <b>Z</b> = 2.1265144 km/sec		
			<b>a</b> = 71.9° <b><math>\gamma</math></b> = 0° <b>ALTITUDE</b> = 100 nm or 185.2 km <b>VELOCITY</b> = 25.561.2 ft/sec <b>LATITUDE</b> = 28.4998° <b>LONGITUDE</b> = -80.5559° <b>INCLINATION</b> = 33.4°		
			<b>X</b> = 1401.8220 nm <b>Y</b> = 2759.5136 nm <b>Z</b> = 1726.1061 nm <b>X</b> = -4.653571 nm/sec <b>Y</b> = -3.313497 nm/sec <b>Z</b> = 1.5145279 nm/sec		
			<b>X</b> = 2596.1745 km <b>Y</b> = 5110.6192 km <b>Z</b> = 3196.7486 km <b>X</b> = -8.6184135 km/sec <b>Y</b> = -6.1328197 km/sec <b>Z</b> = 2.8049057 km/sec		
			<b>a</b> = 72.93° <b><math>\gamma</math></b> = 0° <b>ALTITUDE</b> = 100 nm or 185.2 km <b>VELOCITY</b> = 35,893.69 ft/sec <b>LATITUDE</b> = 29.0997° <b>LONGITUDE</b> = 100.6603° <b>INCLINATION</b> = 33.4°		

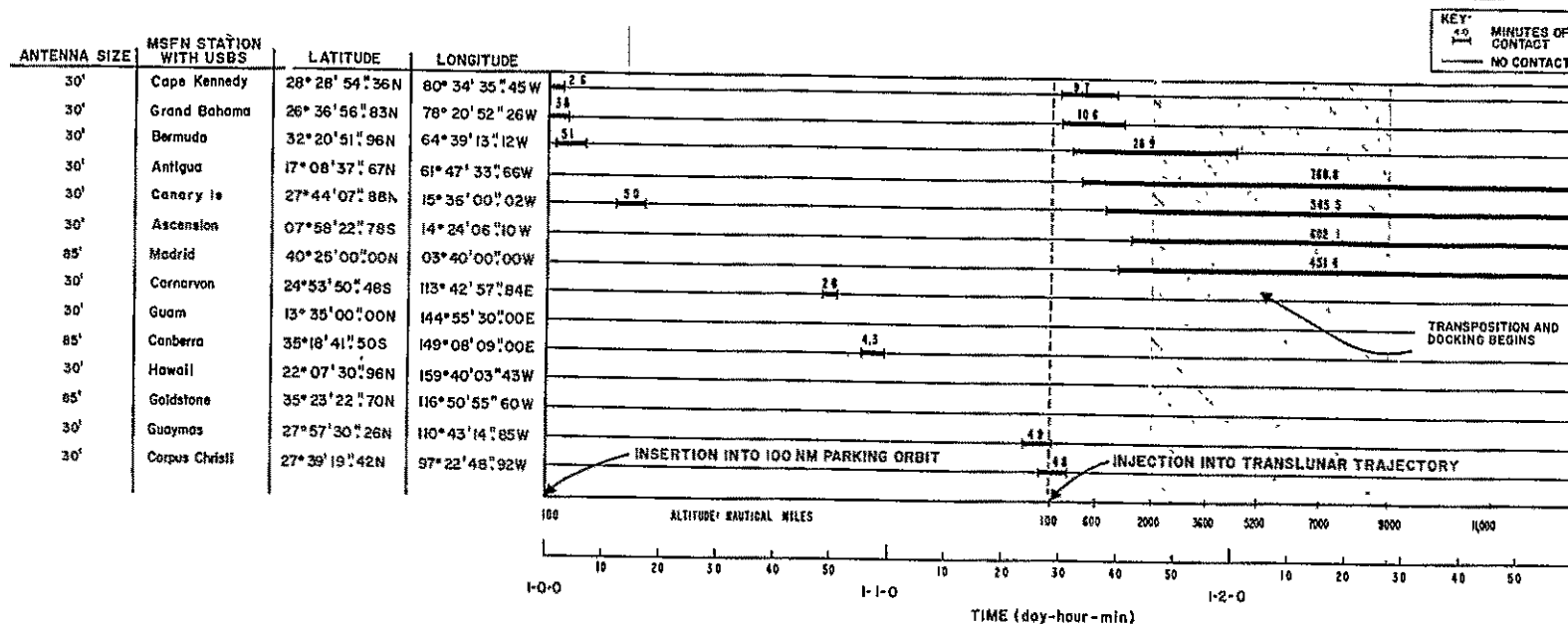


Figure 27—AES Lunar Mission Station Coverage for Earth Parking Orbit and Translunar Trajectory,  $\epsilon \geq 5^\circ$

# AES LUNAR MISSION

## STATION COVERAGE FOR EARTH PARKING ORBIT AND TRANSLUNAR TRAJECTORY $\epsilon \geq 5^\circ$ , FIRST through THIRD DAY

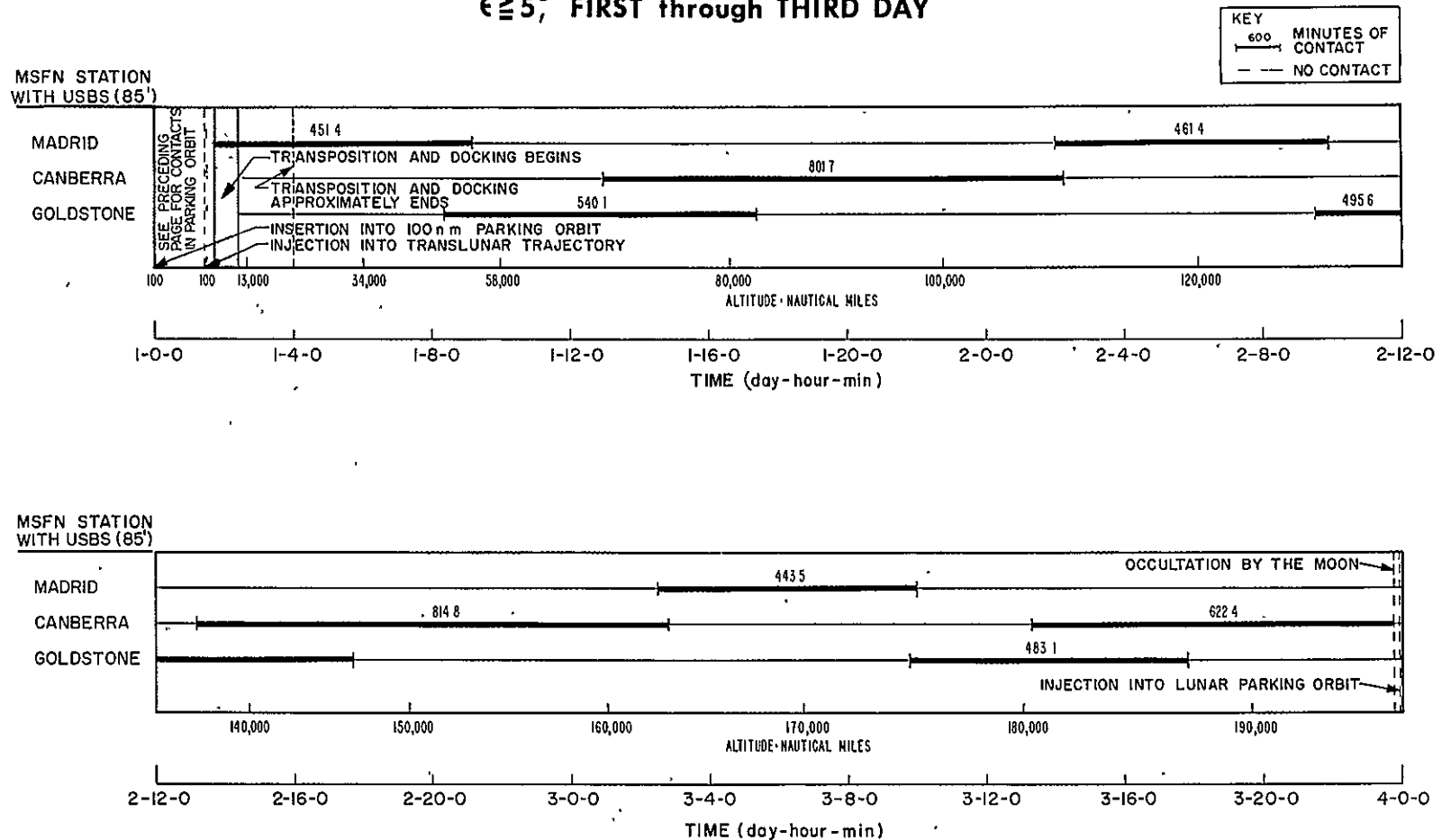


Figure 27 (Continued)--AES Lunar Mission Station Coverage for Earth Parking Orbit and Translunar Trajectory,  $\epsilon \geq 5^\circ$ , First through Third Day

# AES LUNAR MISSION

## STATION COVERAGE FOR EARTH PARKING ORBIT AND TRANSLUNAR TRAJECTORY

$\epsilon \geq 5^\circ$  FIRST DAY

PARKING ORBIT ORBITAL PARAMETERS AT INSERTION				INSERTION FROM PARKING ORBIT INTO TRANSLUNAR ORBIT			
OSCULATING ELEMENTS		POSITION AND VELOCITY		POSITION AND VELOCITY			
T = 17 SEPT. 1969 13 <sup>h</sup> 17 <sup>m</sup> 26.308 <sup>s</sup>	X = -1303 7216 nm	X = -2414.4924 km	q = 71.9°	X = 1401.8220 nm	X = 2596 1745 km	a = 72.93°	
a = 3543.9327 nm or 6563 3634 km	Y = 2827 0379 nm } or	Y = 5235 6742 km	γ = 0°	Y = 2759.5136 nm } or	Y = 5110.6192 km	ALTITUDE = 100 nm or 185.2 km	γ = 0°
e = 0.00017263	Z = 1693 4078 nm } or	Z = 3136.1913 km	ALTITUDE = 100 nm or 185.2 km	Z = 1726.1061 nm } or	Z = 3196.7486 km	VELOCITY = 35,893 69 ft/sec	
i = 33.393467°	X = -3 3699576 nm/sec	X = -6.2411614 km/sec	VELOCITY = 25,561 2 ft/sec	X = -4 653571 nm/sec	X = -9.6184135 km/sec	LATITUDE = 29.0997°	
Ω = 59.217340°	Y = -2 2425345 nm/sec } or	Y = -4.1531739 km/sec	LATITUDE = 28.4999°	Y = -3 3113497 nm/sec } or	Y = -6.1326197 km/sec	LONGITUDE = -100.6583°	
ω = 330.062010°	Z = 1 1493058 nm/sec } or	Z = 2.1285144 km/sec	LONGITUDE = -80.5999°	Z = 1.5145 279 nm/sec	Z = 2 8049057 km/sec	INCLINATION = 33.4°	
M = 89 874900°			INCLINATION = 33.4°				

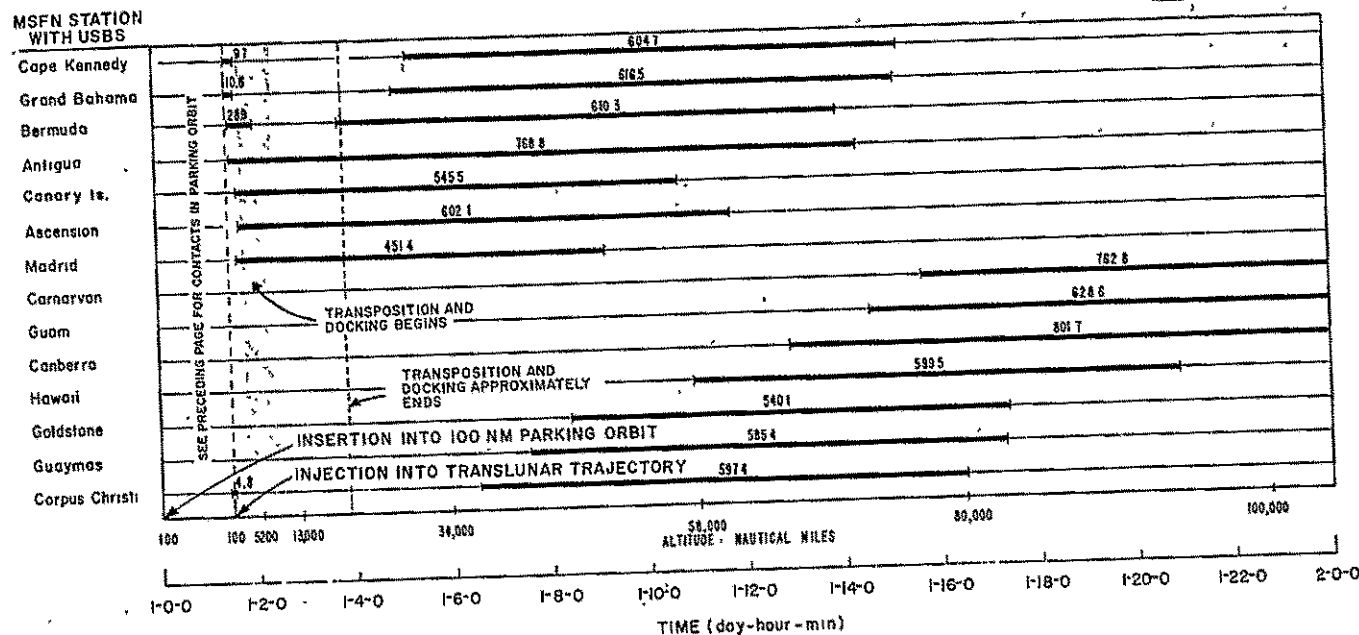


Figure 27 (Continued)—AES Lunar Mission Station Coverage for Earth Parking Orbit and Translunar Trajectory,  $\epsilon \geq 5^\circ$  First Day

# AES LUNAR MISSION

## STATION COVERAGE FOR EARTH PARKING ORBIT AND TRANSLUNAR TRAJECTORY $\epsilon \geq 5^\circ$ , SECOND DAY

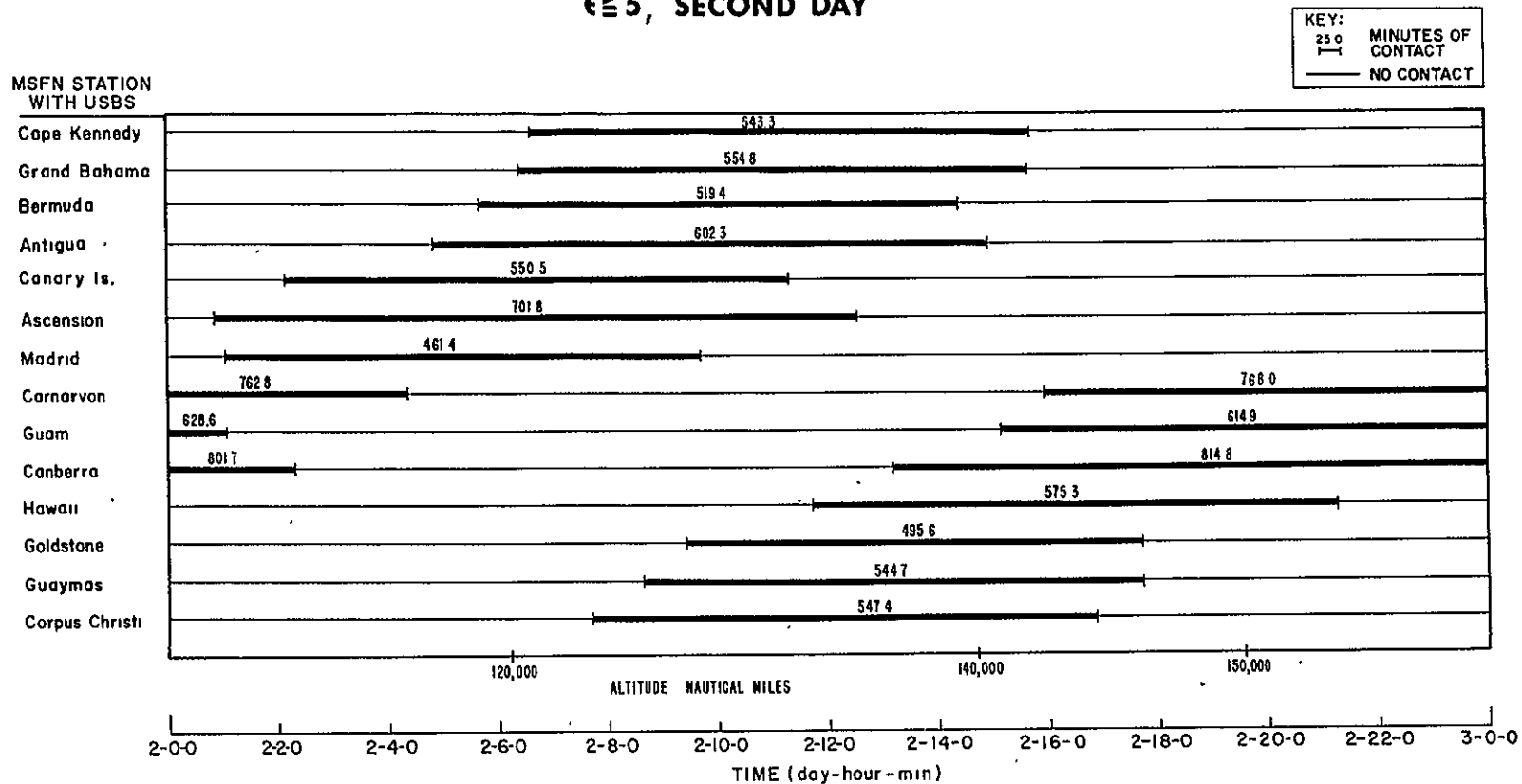


Figure 27 (Continued)—AES Lunar Mission Station Coverage for Earth Parking Orbit and Translunar Trajectory,  $\epsilon \geq 5^\circ$ , Second Day

# AES LUNAR MISSION

## STATION COVERAGE FOR EARTH PARKING ORBIT AND TRANSLUNAR TRAJECTORY

$\epsilon \geq 5^\circ$ , THIRD DAY

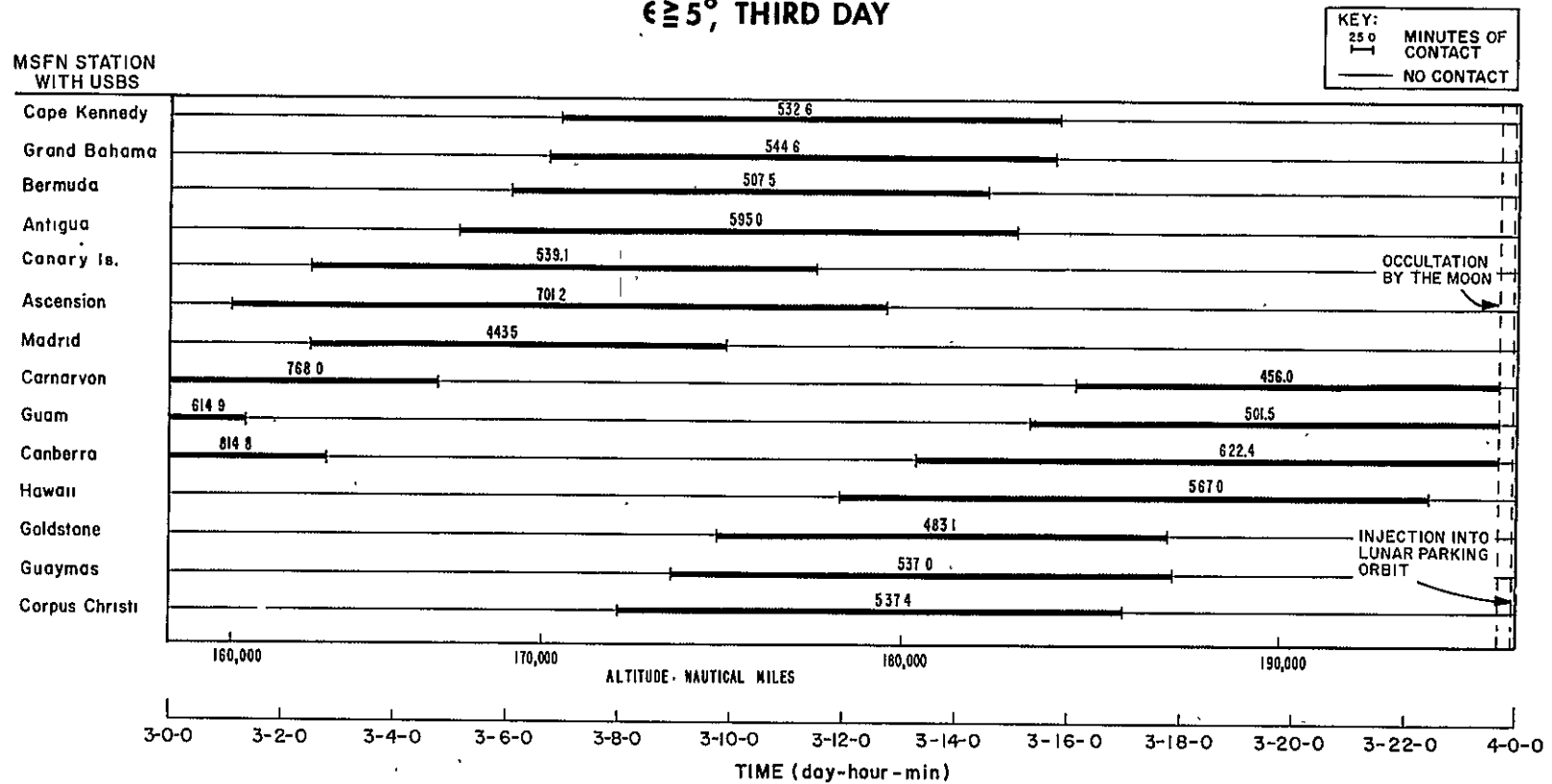


Figure 27 (Continued)--AES Lunar Mission Station Coverage for Earth Parking Orbit and Translunar Trajectory,  $\epsilon \geq 5^\circ$ , Third Day

### 3. Spacecraft to Ground Data Transfer Analysis

#### a. Method of Analysis

The results of the visibility analysis described in Part II of this chapter have been utilized to ascertain the contact time per day in compliance with the minimum telemetry requirements (ground rule 11). Contact time is defined as the duration of the pass of a spacecraft while it is in rf-sight of a tracking station at an elevation angle of 5 degrees or greater (ground rule 12). The maximum contact time for one station is eight minutes when the spacecraft passes directly overhead at an altitude of 200 nautical miles.

The selection of a 5° rf-horizon was based primarily on recent site survey data that showed many stations with terrain masking slightly in excess of 5°. Some stations may possibly see the S/C sooner, however when masking, multipath effects, and S/C antenna orientation are considered, 5° is a reasonable figure.

According to ground rule 11, it is required that the period between consecutive contacts of a minimum four minute duration should not be greater than 120 minutes. A four-minute contact time appears to be a safe average because under weak signal condition it takes a finite amount of time to perform a range measurement on the spacecraft; two minutes is too short, six minutes seems excessively long. Also there is the consideration of computing up-date information. A four-minute contact would certainly provide enough  $X, Y, Z$  and  $\dot{X}, \dot{Y}, \dot{Z}$  for the ground guidance computer. Another reason for the selection of 120 minutes maximum between four-minute contacts is the present Apollo record capability. The play-back ratio may be 1:1 or 32:1. If data is recorded at 1.6 kilobits per second for 120 minutes, then at 32:1 playback it would require  $120 \div 32 = 3.75$  minutes dump time plus a nominal 20 seconds acquisition time or a total of 4 minutes 5 seconds. Although a minimum four-minute contact is required for complete data transfer, any contact that provides some data transfer time should be used. Therefore, all contacts of one minute duration or more have been considered and included in the totals for contact time and net data transfer time.

The net data transfer time is defined as the time available for transmitting data from the spacecraft during contact with the ground stations. For the computation of the receiving capability of experimental AES data, it was assumed that one carrier be reserved for

handling spacecraft housekeeping data. In computing the total net transfer time for experimental data per day, consideration has been given to the fact that some of the MSFN stations have dual USBS receiving equipment and others have single USBS receiving equipment (Table 13). Furthermore, taken into account was the effect of station overlap occurring for a period of time when two or more stations have simultaneous contact with the spacecraft. A scheme for computing net data transfer time during station overlap is diagrammatically depicted in Figure 28. The net contact time for each individual station is indicated by a solid line while the contact time lost due to overlap is identified by a broken line. Data transfer time is subsequently obtained by multiplying the net contact time by the number of data carriers available at each ground station (factor two for dual USBS and factor one for single USBS stations). Consequently, for the 14 minute total net contact time of this example a total of 26 minutes is available for data transfer from the spacecraft to the ground. The data receive capabilities of the MSFN Unified S-Band stations are tabulated in Part II of the GSFC AES study.

Consideration has been given to loss of data receiving time due to spacecraft acquisition and reacquisition. For purposes of this study, 33 min/day has been used for acquisition time. This acquisition time is based on an average of 100 station contacts in a 16-orbit-day. A typical station contact may require as much as 20 seconds for acquisition. Acquisition time in a day period is calculated as follows:

$$\frac{100 \text{ contacts/day} \times 20 \text{ sec/contact}}{60 \text{ sec/min}} = 33 \text{ minutes/day}$$

Thirty-three minutes have been deducted from the daily data receive capabilities for single stations and for sites with dual capability,  $7/14 \times (33) + 33$  or 49.5 minutes were deducted.

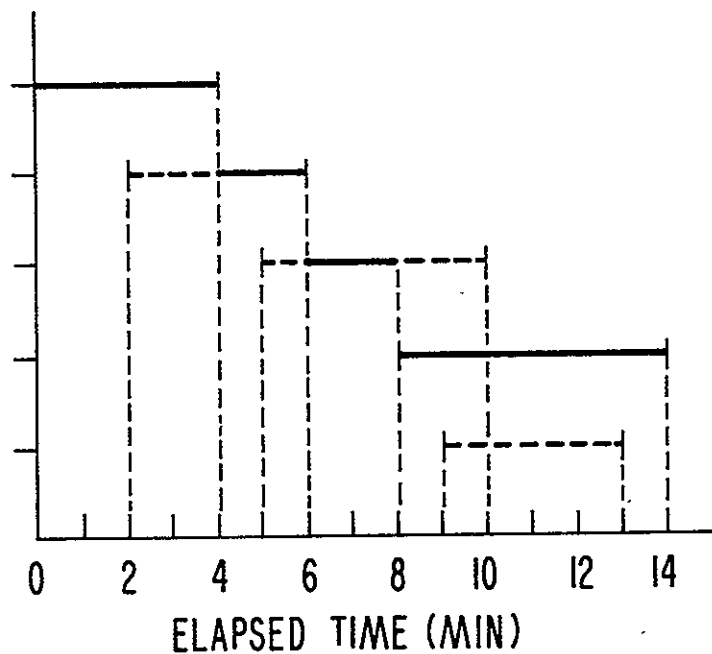
At present, 14 of the MSFN stations have the capability to receive VHF telemetry data. As far as data transmission capability is concerned, retaining one VHF link increases the data transmission capability by a factor equivalent to one carrier. Since the VHF ground equipment functions independently of the USBS, it may be utilized for the full net contact time between the spacecraft and the MSFN.

Table 13  
MSFN Stations With USBS

Dual USBS	Single USBS
Cape Kennedy Ascension Island Madrid Carnarvon Guam Canberra Hawaii Goldstone	Grand Bahama Bermuda Antigua Canary Island Guaymas Corpus Christi

STATION    TYPE

- 1    DUAL USBS
- 2    DUAL USBS
- 3    SINGLE USBS
- 4    DUAL USBS
- 5    SINGLE USBS



---


$$\left. \begin{array}{l} \text{NET DATA TRANSFER TIME} \\ \text{FOR 14 MINUTE CONTACT} \end{array} \right\} = \left\{ \begin{array}{l} 2 \times 4 \text{ MIN} + 2 \times 2 \text{ MIN} + 1 \times 2 \text{ MIN} + \\ 2 \times 6 \text{ MIN} + 1 \times 0 \text{ MIN} = 26 \text{ MINUTES} \end{array} \right.$$


---

Figure 28—Scheme for Computing Net Data Transfer Time During Station Overlap

b. Summary of Results

(1) Near Earth Orbital Missions

Table 14 lists those time intervals for the various orbit types of the AES missions which do not meet the requirement that the time between consecutive four-minute telemetry contacts shall not exceed 120 minutes.

Table 14  
Apollo Extension System (Earth Orbital Missions)

Time Intervals in Excess of 120 Minutes Between  
Successive Contacts of Four or More Minutes Duration  
Using MSFN (USBS)

Orbits 1-48

Orbital Inclination	From D-H-M	To D-H-M	Total (min)
96.5°	1-13-14.4	1-16-7.8	173**
	2-2-0.5	2-4-58.5	178**
	2-13-46.9	2-16-39.9	173**
90.0°	2-2-0.0	2-4-58.1	178**
	2-13-46.6	2-16-39.7	173**
	3-14-19.1	3-17-12.4	173**
81.5°	1-4-31.6	1-6-47.2	136
	1-14-44.4	1-17-37.4	173**
	2-1-57.2	2-4-54.8	178**
	2-4-2.5	2-7-16.3	134
	3-14-12.2	3-17-5.8	174**
	4-25.2	4-4-22.6	177**
	4-4-30.3	4-6-44.2	134
50.3°	1-14-18.9	1-16-32.3	133
	2-10-11.1	2-13-8.0	177
	2-13-15.9	2-15-29.7	134
	3-9-9.5	3-12-4.9	175
	3-13-47.0	3-16-1.0	134
28.5°	2-12-56.1	2-15-24.5	148

\*Time begins at insertion

\*\*Augmenting Fairbanks with USBS reduces these time intervals to within the limits specified in ground rule 11, in addition to providing substantial contact time for data transmission, and the capability to monitor re-entries from these polar orbits.

D -- Days      H -- Hours      M -- Minutes

Table 15 gives the average net contact times and net data transfer times (minutes per day) provided by the MSFN (as presently configured) for the various AES near earth orbital missions. Also, this table gives the additional net data transfer times which could be obtained by:

- a. augmenting Fairbanks, Alaska with a dual USBS
- b. changing four of the six MSFN stations with single USBS to dual USBS
- c. using one VHF link at each of 14 MSFN stations.

The four stations (Bermuda, Guaymas, Antigua, and Texas) were chosen in (b) because of their location and good ground communication links which makes them well suited for dumping "prime" real time data in or near the U.S.

The Apollo Command/Service Module (CSM) will have four VHF links until about Flight 503 or until such time that the USBS has been adequately tested and proven out. After that the CSM VHF equipment is planned to be removed. However, the VHF equipment would be very useful for telemetering the voluminous amount of AES experimental data to the ground. Hence Table 15 shows the net data transfer time which could be gained by retaining only one VHF link in the CSM. If all four VHF links are retained, then these data transfer times may be increased by a factor of four.

## (2) Synchronous Orbital Missions

Coverage for the synchronous orbit launch and insertion into 100 nm parking orbit would be similar to the other 28.5° inclination orbital missions. The Atlantic insertion ship could cover insertion. However, as can be seen by referring to Figure 22, which gives the "ascent" trajectory into a synchronous orbit with a "hover" point at the equator north of Australia, the first plane change and injection into a transfer elliptical orbit takes place where there is no coverage. Hence, one of the ships with USBS should be used to cover this plane change. One suggestion is that the two Indian Ocean ships and the Pacific Ocean ship could be moved to more optimum positions for covering this synchronous orbit. One ship could be moved to the west coast of Africa south of Kano at about 12°E longitude and 4°S latitude. The other ship could be moved close to Tananarive. Then there would

Table 15  
 APOLLO EXTENSION SYSTEM (Earth Orbital Missions)  
 Average Net Data Transfer  
 Times (Min/Day)\*

	Orbital Inclination				
	96.5°	90°	81.5°	50.3°	28.5°
MSFN USBS Stations (Present Capability)					
(1) Total Net Data Transfer Time (one experimental channel)	140	146	162	285	348
(2) Total Net Data Transfer Time with 8 dual and 6 single USBS	260	272	270	466	511
Fairbanks, Alaska (Augmented with dual USBS)					
Total Net Data Transfer Time	81	75	99	—	—
Additional Net Data Transfer Time by changing 4 of the 6 single USBS of the MSFN to dual USBS**	23	23	45	77	64
VHF at MSFN Stations					
Total Net Data Transfer Time for one VHF Link	173	179	195	318	381

\*Times available for transferring experimental data since housekeeping data transfer and acquisition times have been subtracted.

\*\*The four stations (Bermuda, Guaymas, Antigua, and Texas) were chosen because of their location and good ground communication links which makes them well suited for dumping "prime" data in or near the Continental U. S.

be complete coverage from the first plane change and injection point throughout the remainder of the ascent trajectory and circularization.

Re-entry from this type of synchronous orbit with an impact in the nominal Apollo impact area is well covered as can be seen from Figure 24 (a map of the re-entry ground trace and coverage). Although a re-entry ship would be used, its coverage is not shown in this figure.

### (3) Lunar Missions

The nine lunar missions planned for AES should require the same basic operational support as Apollo. However, it is recognized that because of the nature of the AES experiments the total data requirements for the mission will be far in excess of present Apollo requirements. In addition VHF would not be useful for telecommunication at lunar distances. Several possibilities for support of these requirements exist, one is that (at least for early AES lunar missions) all four of the S-Band carrier frequencies be used to transfer data from the spacecraft at lunar distance to the three 85' stations. It appears that this would require the minimum ground system augmentation. If the quantity of real time data still exceeds the link capability then it would seem desirable to redesign the S-Band system both ground and spacecraft to handle higher data rates and band widths. The present MSFN ground stations could handle up to 200 kilobits per second of data with practically no modifications. Of course, the spacecraft equipment Premodulation Processor & Pulse Code Modulation (PMP and PCM) would need to be changed to transmit 200 kilobits per second, or existing spacecraft equipment, such as Spacecraft to Ground Link Subsystem (SGLS) could be used. If it was determined that even higher data rates were required a redesigned link (similar to SGLS) would be in order.

### 4. Data Handling

The experiments which are to be conducted during the AES program have been examined to ascertain the amount of data and the data rates required of the telemetry receiving equipment. More recent material prepared specifically for the AES program has been analyzed. This includes reports noted in references 2, 4, 5, 8, and 9. The information presented therein is not conclusive as to the exact amount of experimental data which will be transmitted during the AES missions. There is every indication that data transfer time required

will be considerably in excess of that required for the Apollo mission. It may be reasonably assumed that some of the operational data, needed for Apollo, may not be required during the AES missions. Even so, the evidence indicates that the total data requirement will still be far in excess of the Apollo requirement. The net data transfer times may require 500 to 600 minutes per day for receiving AES data. Our own analysis based upon the data supplied to NASA Headquarters by IBM, suggests that an even greater data transmission capability may be necessary.

Moreover, since 24 missions are being scheduled over a relatively short period of time, the interval between missions is quite brief. And since data from a given experiment should be analyzed prior to the initiation of a subsequent similar experiment in a later flight, a large portion of the data must be communicated to the Mission Control Center by NASCOM with minimum delay.

Preliminary estimates of the total information bandwidths generated while the AES experiments are in progress in the spacecraft indicate that additional telemetry links will be required (USB or VHF) to handle high information earth survey and mapping data. In addition, it should be noted that television transmissions of near commercial quality (4 megacycle bandwidth) have been specified in connection with some of the spacecraft experiments. (See Table 11 for data handling capability of MSFN USB equipped ground stations.)

To accommodate a modest portion of this increased data handling requirement, it is necessary that the data processing equipment at the USBS stations be augmented by approximately 30%. Also, the NASCOM communication facilities should be improved; this is discussed under the appropriate heading. The equipment augmentation for existing USB stations (excluding GBI) includes data decommutators, data processors, wideband recorders, TV recorders, scan converters, and TV displays.

## 5. Tracking Ships and Aircraft

To supplement the ground tracking stations of the GSFC Network a number of ships and aircraft have been acquired and are instrumented to perform certain tracking and data handling functions.

#### a. Tracking Ships

Five ships are currently in the process of conversion and instrumentation. Three of these ships are converted tankers and are instrumented to function as mobile range stations during the insertion and post-injection phase of the Apollo or similar mission. (See ref. 10). The remaining two ships are modified Victory Ships, instrumented for use during the re-entry phase of an Apollo or similar mission.

The ships carry the same type of equipment as is installed in the ground stations. This includes Unified S-Band, C-Band Radars, data handling and communication equipment. Two of the converted tankers are injection ships and have dual S-Band receivers (4 channels). The other converted tanker, used for insertion, and the re-entry ships have single S-Band receivers (2 channels).

The re-entry ships will be equipped with active pulse radar for acquisition and tracking during the ionization blackout phase at re-entry. The re-entry ships do not have command capability.

For communication between ship and shore, the ships rely on HF communication links. In the present configuration, the data rate is limited to a maximum of 2400 bits per second. Ionization layer sounding equipment is employed to ascertain the optimum frequency of transmission. Real time high speed data transmission between ship and shore could be established on a reliable basis by use of a communication satellite.

In addition to the Unified S-Band capability, the ships are adequately equipped for the reception of telemetry in the 2200 to 2300 Mc band and in the 225 to 260 Mc band. Decommultiplexing and limited data processing facilities are available on board.

The ships are inherently subject to a number of operational limitations. The "Away from Port" period for the insertion-injection ships is sixty days. For the re-entry ships the period out of port is 45 days. The sustained velocity of the re-entry ships is 10 knots resulting in a movement of about 240 nautical miles per day.

Because of the ship's motion, the tracking accuracy of shipborne tracking systems is less than the same land based systems. However, for the reception and recording of telemetry or voice communication, the ships are comparable with similar land based facilities.

For the AES Program, one of the insertion-injection ships will be employed for insertion coverage for the missions utilizing the Saturn V. This ship will also serve as back up and supplementary coverage for other missions when available. The schedule does not indicate that multiple Saturn V launchings are anticipated so that one ship should be capable of coverage for all insertions which take place in the Atlantic area.

The injection ships will cover the post injection phase of the lunar missions in much the same manner as in the Apollo mission. In addition, these ships may be utilized, where needed, in specified phases of other missions. The areas of possible utility are listed in the following:

- (1) Post retrofire tracking for near-earth (200 nautical miles) orbits of  $28.5^\circ$  inclination. For this service, the ship would be stationed in the proximity of East Indies or the Philippine Islands depending on the particular trajectory.
- (2) Insertion into the  $96.5^\circ$  or the  $90^\circ$  inclination orbit at 200 nautical miles altitude. For this purpose, the ship would be stationed near the Galapagos Islands off the coast of Ecuador. (See Figure 8).
- (3) Insertion into the  $81.50^\circ$  inclination orbit at 200 nautical miles altitude. The ship would be stationed near Esmeraldas, Ecuador.
- (4) Post retrofire or pre-re-entry tracking for the  $96.5^\circ$ , the  $90^\circ$ , or the  $81.5^\circ$  orbit. It does not seem practical to make this observation within five minutes of the retrofire; however, an observation at a latitude of about  $50^\circ$  North or  $50^\circ$  South (depending on the approach) should prove most desirable. For the north approach, the ship would be south of the Aleutians. For the south approach, the ship would be stationed east of New Zealand at a longitude of about  $155^\circ$  East.
- (5) An injection ship could be stationed near the north-end of the Red Sea to observe Service Module Perigee Maneuvers of the Hohmann transfer used on the  $50.3^\circ$  inclination orbit. Apogee maneuvers could be observed by the station at Canberra.
- (6) Post retrofire tracking may be accomplished for the  $50.3^\circ$  inclination orbit by a ship stationed north of Madagascar.

- (7) In the  $28.5^\circ$  inclination synchronous orbit, the insertion ship, stationed 1200 nautical miles east and slight south of Bermuda will track the first burn of the S-IVB. The second burn of the S-IVB will be tracked by an injection ship located just south of Madagascar.
- (8) In the same mission, the burn of the service module to establish a circular orbit may be tracked by the second injection ship located near Rarotonga ( $160^\circ\text{W}$ ,  $21^\circ\text{S}$ ). This could also be done by the South Pacific Re-entry Ship if it is more convenient at the time.
- (9) An injection ship, located 1200 nautical miles west of Carnarvon, Australia, could track the post retrofire trajectory of the  $28.5^\circ$  synchronous mission.

The schedule for the AES mission does not indicate that under normal circumstances, simultaneous re-entry of two or more spacecraft may be expected. If, as anticipated, the re-entry area is kept in the Pacific Ocean, somewhere in the proximity of Hawaii or Samoa, the two re-entry ships with suitable supporting facilities will be capable of covering all normal missions.

#### b. Aircraft

Since nine of the AES missions follow lunar trajectories, the communications aircraft will be used during the departure and return phase of these programs.

There are other normal situations where the aircraft can be employed during the AES program. For example, in any transfer (except in the equatorial plane) from a parking orbit, the location of the "burn" window precesses when a delay of one or more orbits becomes necessary. This precessing is similar to the precessing of the Apollo injection window, and can be covered by aircraft in a similar manner.

The aircraft are equipped with S-Band data recording equipment and may be used as supplemental data recording. The mobility of the aircraft can provide a temporary recording site in remote and difficult locations.

## 6. Ground Communications Analysis

Perhaps the greatest difference between the AES program and the Apollo program, as far as its impact on the communications system is concerned, is the increase in the amount of data that has to be transferred to MCC-H because of the experiments being conducted onboard the spacecraft throughout each mission. The constraints imposed upon mission operations and objectives due to limitations of overseas communication links are all too evident. A review of Table 11 and a knowledge of the AES spacecraft air-to-ground communication links indicates a data dump rate that is only limited by the spacecraft instrumentation and not by the ground station data handling capacity. However, the real constraint in the transfer of operational and experimental data to MCC-H is due to the narrow band conventional communication circuits which are the best facilities presently available to the overseas MSFN ground stations. An analysis of the various AES missions with the resultant awareness of the limited amount of real-time data transmission time makes it quite apparent that it will be necessary to augment the NASCOM Network in order to to minimize or eliminate the constraints of the existing communications circuits.

The augmentation of the NASCOM Network may take one of two forms: the installation of store-and-forward switching equipment at the remote ground stations of the MSFN to make the existing ground communications system more efficient and reliable in handling real-time and near-real-time data on a narrow band basis; or the installation of a communication satellite system to provide for all of the required data to be handled on a real-time wideband data transfer to MCC-H.

### a. Store-And-Forward Switching Equipment

Although no definite information is available on the amount of increased data transfer that is expected as a result of the experiments to be conducted onboard the spacecraft during the AES missions, any increase in data transmission over that planned for Apollo will require some augmentation of the NASCOM Network. With the limited number of overseas communications channels available via the submarine cables extending from North America across the Atlantic and Pacific Oceans, it is very doubtful if additional channels can be obtained above those already planned for support of NASA projects. The installation of a store-and-forward switching system at the USB ground stations will result in more efficient use of the existing communications system by permitting the transmission of more traffic per circuit.

At the present time six (6) alternate voice/data and two (2) teletype circuits are planned to each of the remoted Unified S-Band sites of the MSFN. The six voice/data circuits are planned for various functions such as voice coordination, biomed data transfer, telemetry and command data transmission. Figure 29 illustrates an arrangement of six point-to-point circuits which are configured in a manner similar to that presently planned for Apollo mission support. Reference to the trunk capacity curves of Figure 30 which was developed from Trunk Capacity Tables published by the American Telegraph and Telephone Company indicates that for a grade of service of .01 the traffic capacity per link is about .5 unit message. The six links would thus provide for a total traffic capacity of 3.0 unit messages. A unit message is defined as 100 seconds of circuit utilization. However, if both ends of the trunk group are provided with switching facilities, such as is proposed for AES, those same six voice/data circuits would have a total traffic capacity of 64.5 unit messages for the same grade of service (See Figure 29). This comparison of two different configurations for the same trunk group demonstrates a more than twenty fold increase in efficiency that can be obtained.

#### COMPARISON BETWEEN POINT-TO-POINT CIRCUIT ARRANGEMENT AND CIRCUIT SWITCHING

Apollo (Present)	6 trunks, point to point (99% CA)	3.0 UM
AES (Recommended)	6 trunks circuit switching (99% CA)	64.5 UM

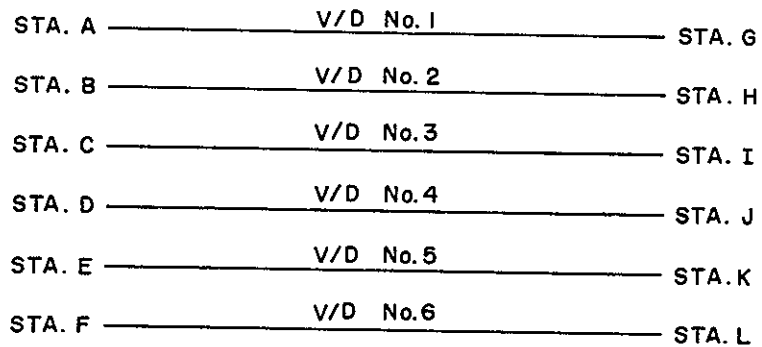
$$\text{Utilization Improvement Factor} = 64.7/3.0 = 22$$

Figure 31 shows three separate trunk groups of two trunks each. Each trunk group handles a traffic load of 15 unit messages. Reference to the trunk capacity curves indicates that the circuit accessibility for these conditions is 93.5%. Another way to state this is to say the 6.5 times out of 100 attempts to use a circuit will result in an all trunks busy condition. If the three trunk groups of two each are combined into one trunk group as in Figure 31 the same total unit calls or unit messages can be handled by five trunks with an increased circuit accessibility of 99.1%, or less than one loss attempt out of 100 at seizing a

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\*CA = Circuit Accessibility

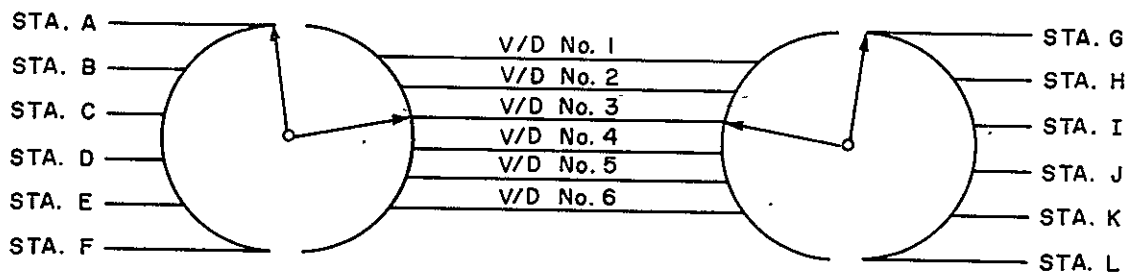
(a.) PRESENT APOLLO CONFIGURATION



GRADE OF SERVICE = .01 \*

TRAFFIC CAPACITY = .5 UM / LINK x-6 = 3.0 UM TOTAL

(b.) RECOMMENDED CONFIGURATION FOR AES



GRADE OF SERVICE = .01 \*

TRAFFIC CAPACITY = 64.5 UM TOTAL

\*OUT OF 100 ATTEMPTS TO USE A CIRCUIT, ONE ATTEMPT WILL RESULT IN AN ALL TRUNKS BUSY CONDITION.

UM - UNIT MESSAGE (100 SECONDS CIRCUIT UTILIZATION)

Figure 29—Circuit Switching

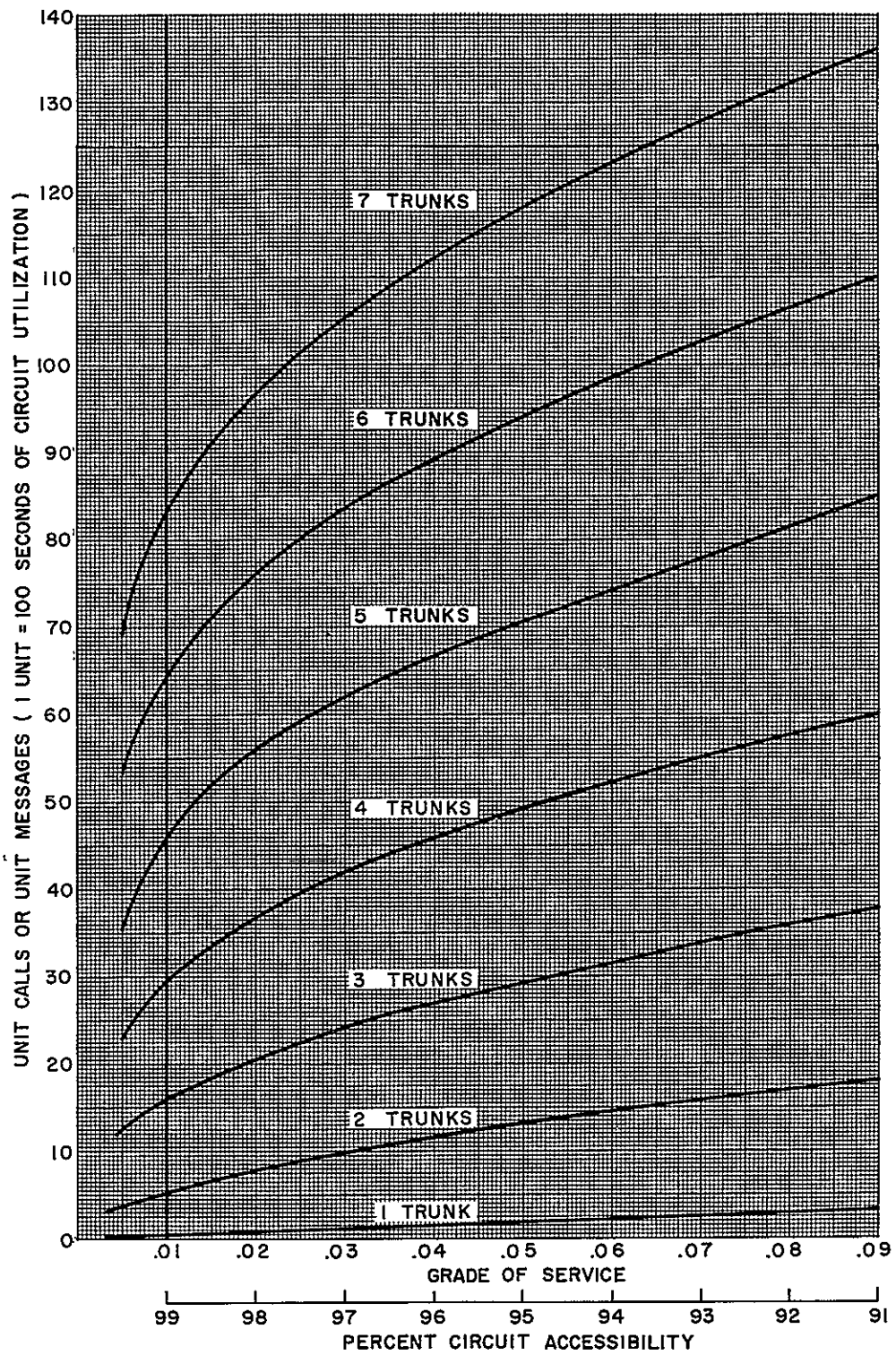


Figure 30—Trunk Capacity

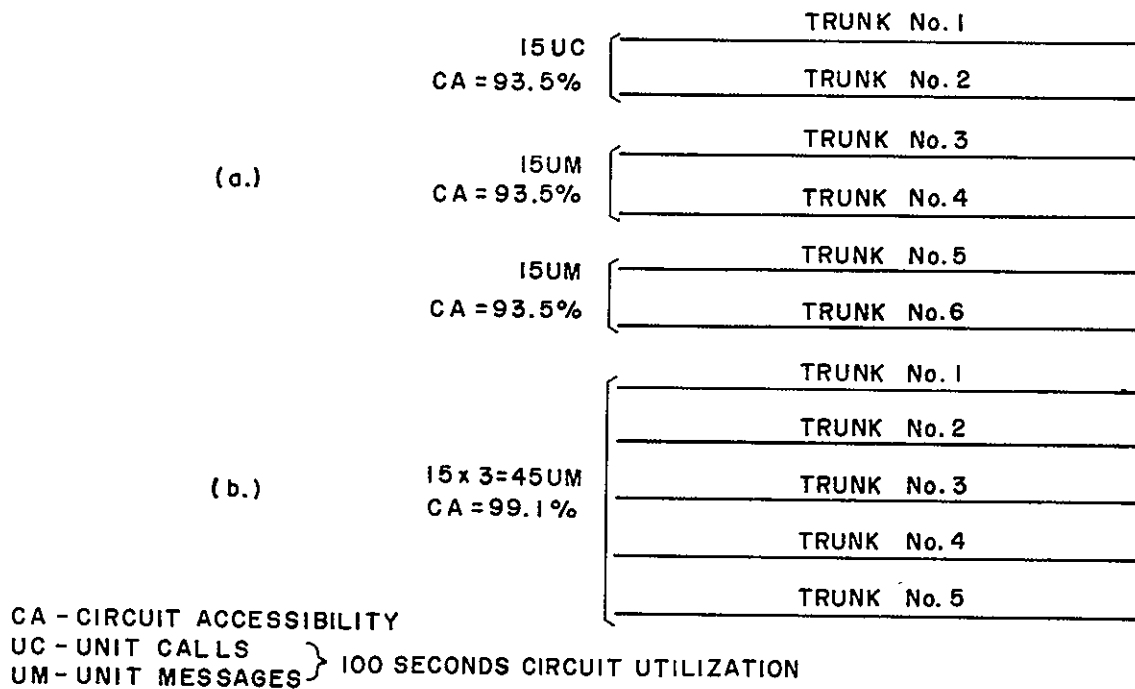


Figure 31—Common Trunking

trunk. Figure 32 shows two different arrangements for six trunks. When they are combined into one group the circuit accessibility is greatly improved. Figure 33 illustrates how the grade of service is affected for these same arrangements of trunks if a fault occurs on one circuit. Again it is demonstrated that the circuit accessibility is much higher when all six trunks are combined into one trunk group.

From the discussion above it is apparent that greater operational efficiency and reliability can be achieved by routing the voice, high-speed data and teletype traffic over a common trunk group. The installation of the store-and-forward switching equipment at the MSFN ground stations will permit this efficient use of the existing ground communications system.

An analysis of three of the types of AES missions which are a part of the GSFC investigation reveals that a very small portion of the available transmission time between the remote ground stations of the MSFN and the MCC-H will actually be used during spacecraft acquisition for transmission of real-time data. For instance, Table 16

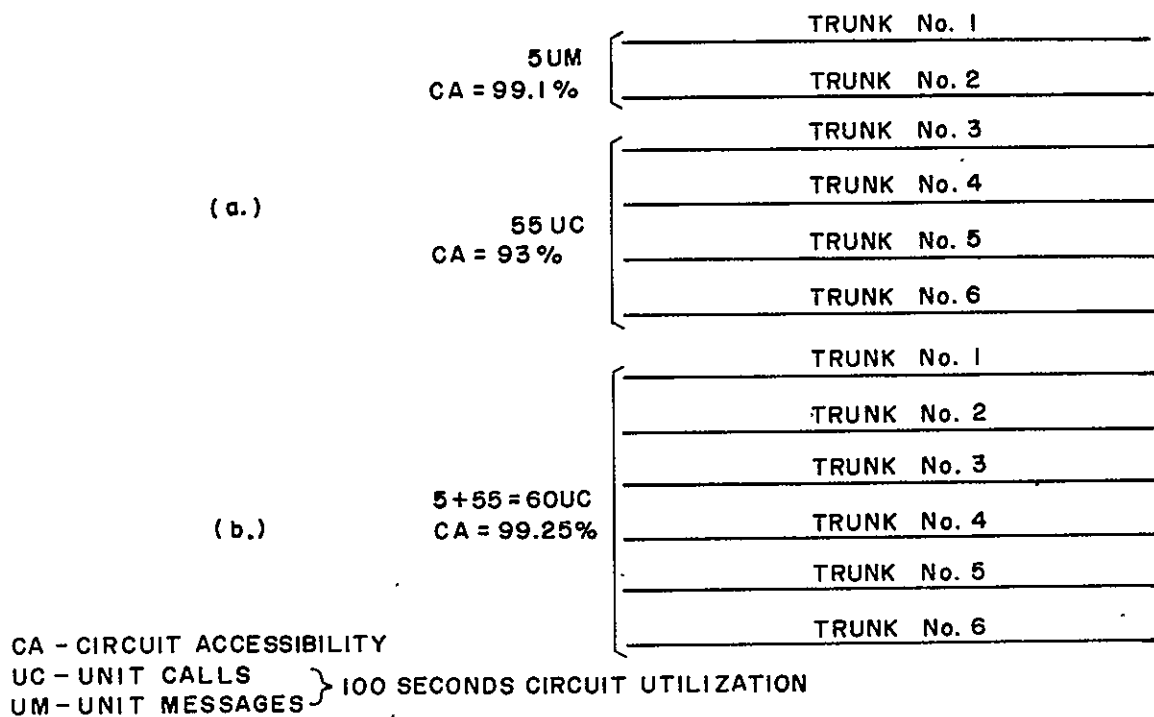


Figure 32-Common Trunking

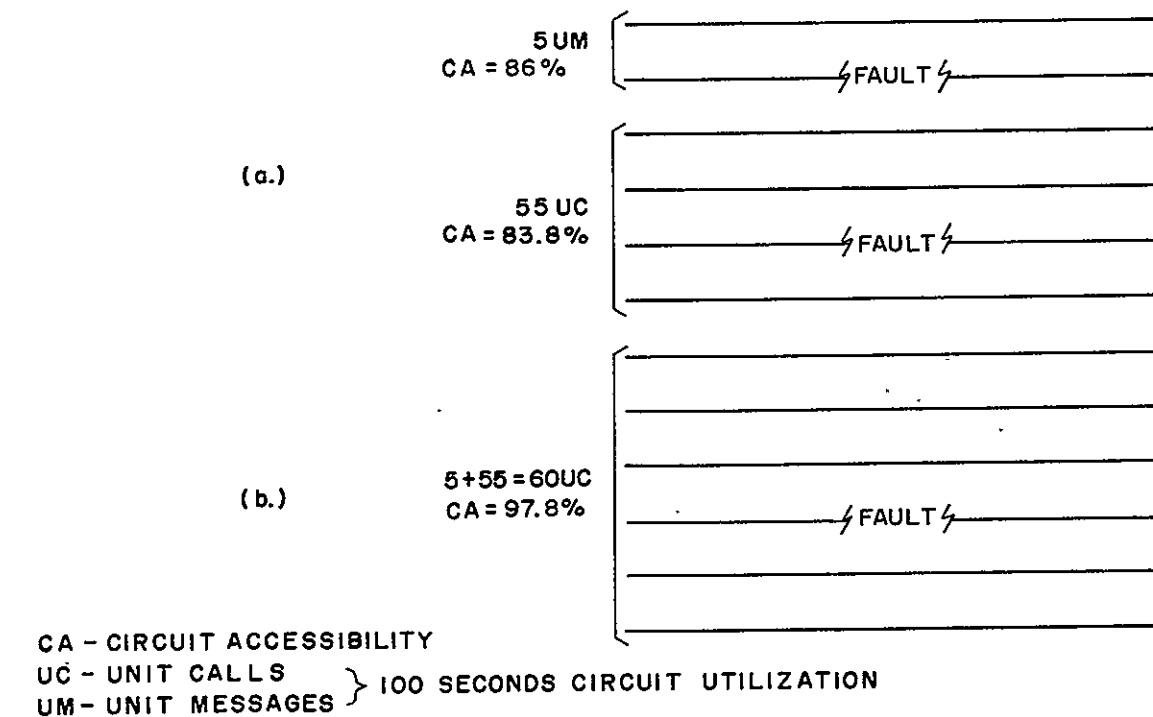


Figure 33-Common Trunking

shows that a circuit from the Pacific area that serves the USB ground stations at Carnarvon, Canberra, Guam, and Hawaii can transfer 50 minutes per day of real-time telemetry data during the 96.5 inclination mission for a 5.1% circuit utilization. This is compared to 924 minutes per day of time between station acquisitions that can be used for the transmission of operational and experimental data that does not need to be transmitted in real-time.

It should be pointed out that the full 924 minutes per day on the transmit leg from the sites cannot be used for the transfer of telemetry data since this leg of the digital data circuit will also be used for the transmission of CADFISS test data and command verification data. In addition, any USB ships which might be positioned in the Indian or Pacific Oceans would increase the amount of real-time and decrease the amount of near-real-time circuit utilization. However, with such a low degree of circuit traffic loading on all of the circuits as indicated by Table 16, it would appear prudent to process the data received by the ground station from the spacecraft to permit the separation of that data which is so vital to the safety of the astronauts or the success of the mission that it has to be transmitted in real-time from the experimental data that could be delayed slightly.

A store-and-forward type switcher would be capable of differentiating between the real-time and near-real-time data as tagged by the telemetry data processor and transmit both in proper sequence with the minimum of delay. The switcher would not only be capable of switching circuits automatically, but would also be capable of transmitting more data per circuit, thus further increasing the efficiency of the communications system. The reliability of the communications system is greatly enhanced by the various performance functions of the solid state switching system.

#### d. Communication Satellite System

A second form of augmentation for the NASCOM Network which is more flexible in meeting the demands of the AES program is the installation of a communications satellite system. A communications satellite system composed of satellite ground terminals co-located

Table 16  
Communication Circuit Utilization

CIRCUIT SEGMENT		REAL TIME (Min/Day)	NEAR REAL TIME (Min/Day)	% REAL TIME
FROM	TO			
i = 96.5°				
ACRO/ABRA	PHON	25	900	2.7
ACRO/ABRA/PGWN/PHAW	GSFC	50	924	5.1
GGYM	GSFC	14	962	1.4
GODS	GSFC	15	975	1.5
GTEX	GSFC	13	982	1.3
GUMI	GSFC	11	875	1.3
GUGB	GSFC	12	876	1.3
GUSC	GSFC	12	926	1.2
GUNT	GSFC	8	792	.9
GBDA	GSFC	14	895	1.3
GLGE	GSFC	33	954	3.3
LCYI/LMAD	GSFC	24	934	2.5
i = 81.5°				
ACRO/ABRA	PHON	27	961	2.8
ACRO/ABRA/PGWN/PHAW	GSFC	54	941	5.4
GGYM	GSFC	14	1142	1.3
GODS	GSFC	17	1140	1.4
GTEX	GSFC	14	1149	1.7
GUMI	GSFC	14	993	1.5
GUGB	GSFC	14	994	1.4
GUSC	GSFC	12	1060	1.1
GUNT	GSFC	11	1018	1.1
GBDA	GSFC	13	992	1.4
GLGE	GSFC	37	1121	3.2
LCYI/LMAD	GSFC	23	1055	2.2
i = 28.5°				
ACRO/ABRA	PHON	57	1039	5.2
ACRO/ABRA/PGWN/PHAW	GSFC	127	1009	11.2
GGYM	GSFC	33	1117	2.9
GODS	GSFC	22	1130	1.9
GTEX	GSFC	34	1128	2.9
GUMI	GSFC	31	1117	2.7
GUGB	GSFC	33	1116	2.9
GUSC	GSFC	30	1114	2.6
GUNT	GSFC	38	1088	3.4
GBDA	GSFC	23	1148	2.0
GLGE	GSFC	-	-	-
LCYI/LMAD	GSFC	28	1184	2.4

with the overseas USB ground stations coupled with the satellite and leased facilities within the continental U.S. would provide real-time, wideband communication channels for data transfer to the MCC-H with high reliability and low error rate.

Figure 34 depicts the configuration of the NASCOM Network using a communication satellite system for the support of the AES program. A multiple access synchronous satellite positioned over the international date-line ( $180^{\circ}$ ) would provide simultaneous communications of approximately 96 KC information bandwidth between MCC-H and the USB ground stations at Carnarvon, Canberra, Guam, Hawaii, Fairbanks, and the Injection Ships in the Indian and Pacific Oceans. A second multiple access synchronous satellite positioned at approximately  $15^{\circ}$  West Longitude would provide simultaneous wideband communications between the MCC-H and the USB ground stations in the Eastern sector, namely, Madrid, Canary Island, Ascension, Bermuda, and the USB Insertion Ship positioned in the Atlantic Ocean.

Using a building block approach to a system design, the basic unit being a 48 KC "Group," the communication compliment at the remote USB ground station and the three USB ships would be configured as follows:

- (1) 48 KC Group - 40.8 KBPS to MCC-H (Telemetry & Biomed)
- (6) 4 KC Voice/Data to MCC-H (Voice, Tracking)
- (1) 48 KC Group - (5) 4 KC Voice/Data from MCC-H (Voice, Command),
- (1) 4 KC Channel (Teletype Mux)

As indicated in the previous paragraph, all of the USB ground stations in the Western Sector will have this communication capability simultaneously as will all of the USB ground stations in the Eastern Sector. An alternate mode of communication operation would permit a single station access to transmit one high quality 4 MC FM video signal which might contain:

- (1) 500 KC information bandwidth TV to MCC-H
- (1) 40.8 KBPS Telemetry & Biomed to MCC-H
- (6) 4 KC Voice/Data to MCC-H for voice and tracking

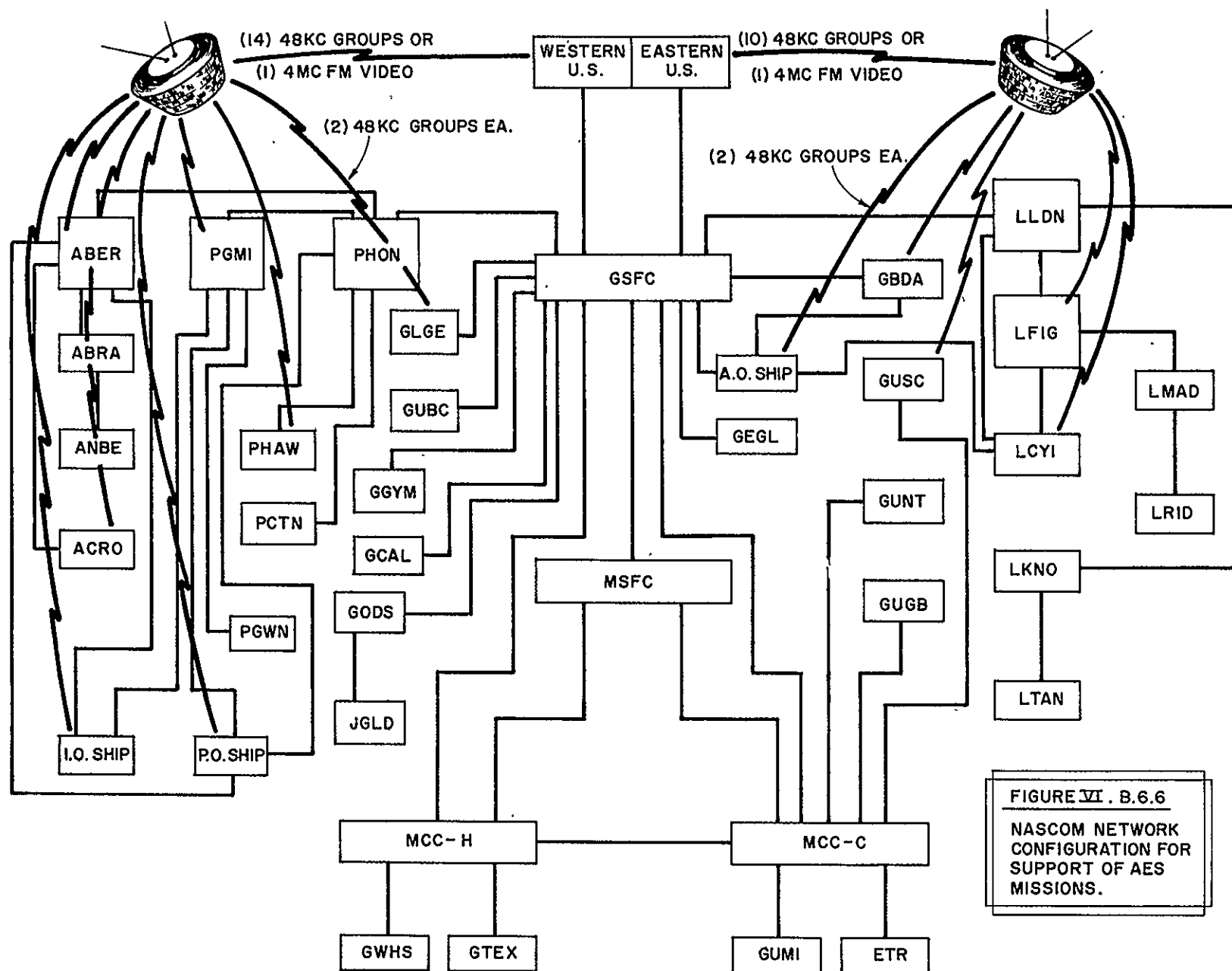


Figure 34—NASCOM Network Configuration for Support of AES Missions

This ground station (Camperra, Madrid) would retain its communication capability from MCC-H as shown for the first mode and the other stations might retain their receive capabilities or might receive on a broadcast basis. A sufficient quantity of conventional communication facilities would be retained to provide the required minimum back-up capability to the communication satellite system and to service those remote ground stations that are not required to transmit data to the control center in real-time.

NOTE:

The type of channelization shown above is suggestive, and could be established for each remote site as required.

The installation of the communication satellite system in lieu of the store-and-forward data switching equipment covered in paragraph 6.B.6a would eliminate the need for the data switcher and would also eliminate the need for some of the equipment planned for the augmentation of the MSFN ground station equipment as stated in paragraph 6.A.2. The system would provide a great deal of flexibility in providing new communications between the ground stations and the MCC-H. At the time that the communications satellite system becomes operational and has obtained the expected level of reliability, the existing or budgeted conventional communications circuits could be reduced to a reasonable backup complement.

## 7. Conclusions

The analysis presented in this chapter has shown that the stations of the MSFN and the NASCOM communication network can be utilized for adequate coverage of the low inclined orbits of the AES missions. Although augmentation is needed in many areas, no new stations need to be established. The deficiencies in the coverage of the high inclination orbits (81.5°, 90° and 96.5°) are corrected by installing S-Band and suitable data handling equipment at the Fairbanks, Alaska, site of the STADAN network. Improved data communication links would be required between this site and the mission control center. The increase in quantity of data per mission and the high mission density during the program will necessitate augmentation in the data handling facilities at these stations and improvements in the ground communication system.

The manifold increase in the operation time of tracking and data communications, as a result of the high mission density, will require continuous operation of approximately 70% of the MSFN stations. This will result in a need for increased operating personnel and associated supporting facilities.

Although no augmentation has been needed for the equipment or maintenance of the ships and aircraft of the MSFN, it can be seen that the AES program will involve much more extensive use of these equipments than is anticipated for the Apollo program. A supplementary funding will be required for financing the increased movement of these vehicles.

In addition, it has been shown that the data transmission between the spacecraft and the ground network can be improved by increasing the receiving facilities at four USBS stations of the MSFN. This modification will make data transmission in the spacecraft less complex, and will also simplify the data communication aspects in the mission planning phase.

During the progress of this study, considerable attention has been given to the utilization of a communication satellite for the transmission of information between the stations and the mission control center. The satellite communication system entertains some very attractive features which are quite desirable for the network. However, there are still some questions concerning some aspects of the system, such as reliability, maintainability, cost, etc., which should be proven out before existing and established procedures are abandoned.

A complete analysis of the use of the satellite system and its influence on the network is being prepared as an option for the AES program, however, until the system is installed and operating the existing communication methods should be supported.

### C. NETWORK OPERATION

Previous portions of this report have defined the AES network in gross terms of augmentation of the Apollo MSFN. The Apollo network is considered to be clearly defined by the Apollo/Saturn 5 PSR dated April 1965. The basic AES network is, therefore, the Apollo MSFN with the addition of USB equipment of Fairbanks, Alaska, with instrumentation augmentation at 13 USB stations, and with increased M&O personnel at selected MSFN sites and related support areas at GSFC. Since the AES network is essentially the

Apollo network, there is no need to encumber this report with the general subject of network operations. There is need, on the other hand, to show how the augmented MSFN will be controlled, directed, and interfaced with user's during the mission and non-mission periods of AES. Because of the frequency and duration of network support requirements and the extensive implementation, checkout, and pre-mission activities that are becoming routine aspects of operation, the GSFC has established a Network Operations Control Center for 24 hour, 7 day a week network direction and control. This Control Center is currently in operation in support of both scientific and manned satellite programs. The following paragraphs and accompanying figures are intended to briefly define the structure and operation in support of network activities, which are in general composed of mission utilization periods followed by mission support periods.

### 1. Integrated Network Control

Figure 35 describes an organizational arrangement whereby unique spacecraft tracking facilities may be brought together to form an operationally integrated tracking and data acquisition facility. This organization provides direct operational control of the following elements:

- a. STADAN (Satellite Tracking and Data Acquisition Network)
- b. MSFN (Manned Spaceflight Network)
- c. SAO (Smithsonian Astrophysical Observatory Baker-Nunn Optical Network)

Additionally, tracking support is supplied by the U.S.A.F. North American Air Defense Network (NORAD) as required.

### 2. Manned Spaceflight Network Operational Control

Figure 36 describes the necessary functional elements required to provide 24 hour, 7 day a week network activity monitoring and operational control. The described organization is providing extensive support in the accomplishment of the scientific and manned satellite programs in current operation.

### 3. AES Network Utilization and Operational Control

Figures 37 and 38 are set forth to define the specific organizational structure planned to accomplish the AES support.

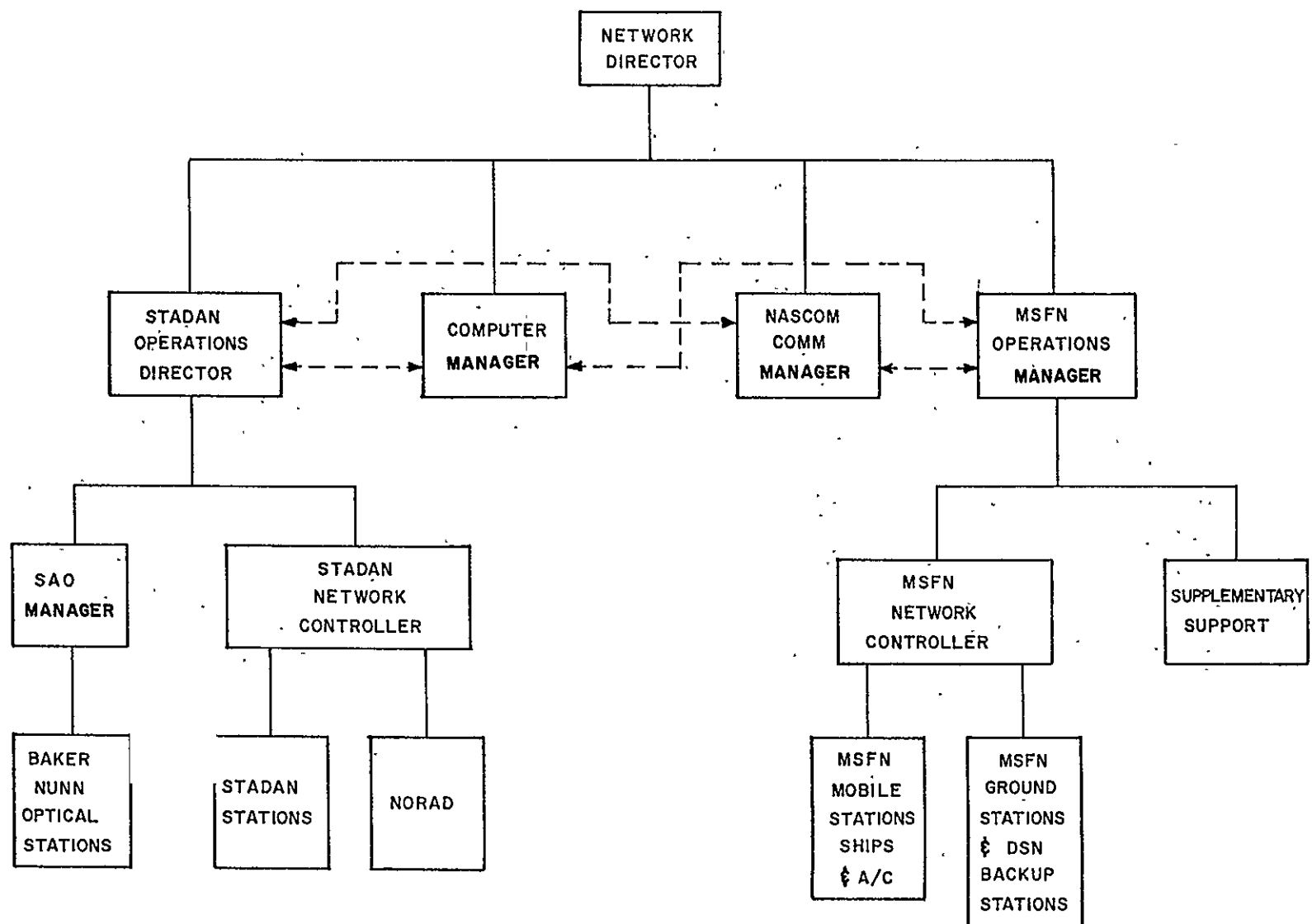


Figure 35—Integrated Network Control

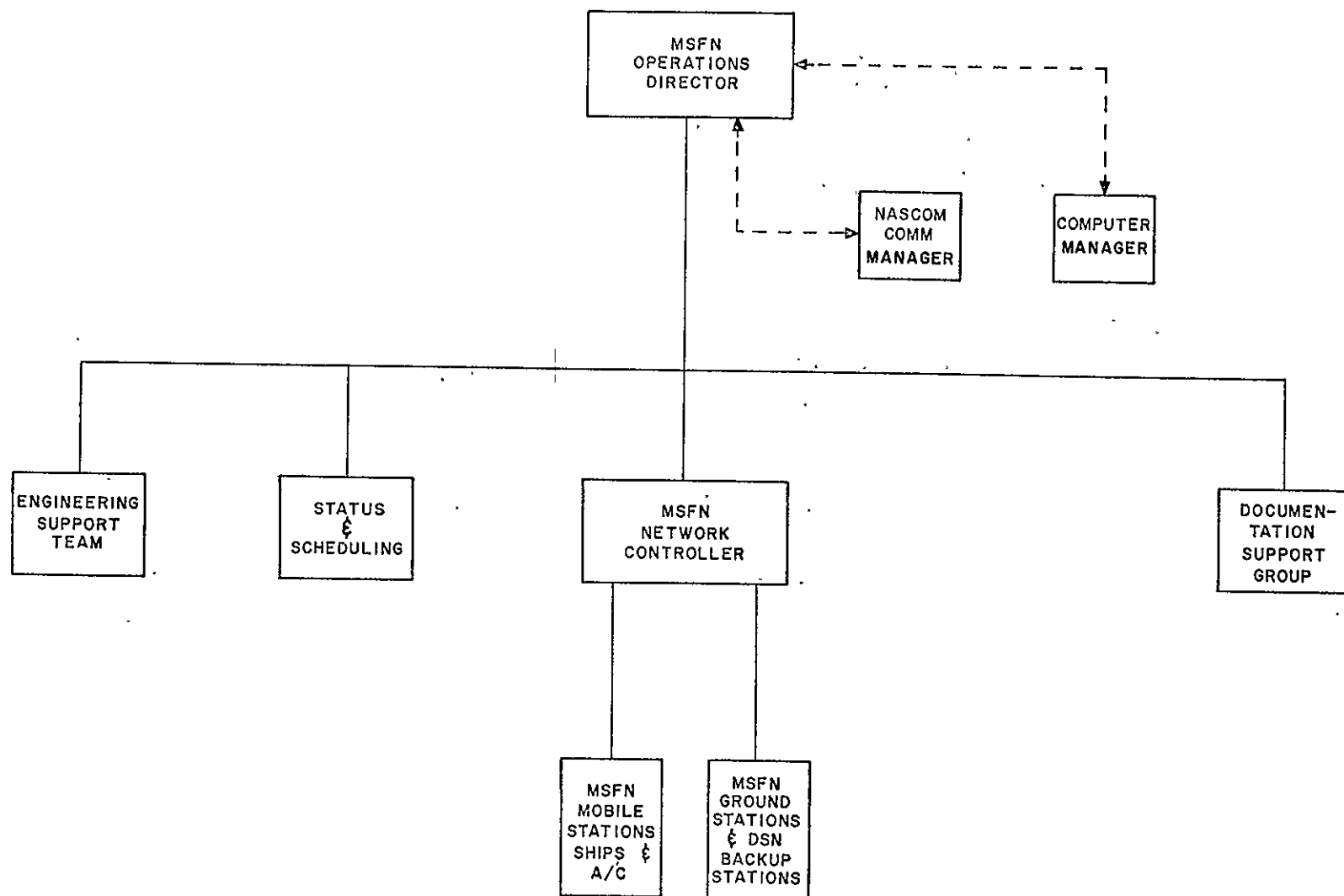
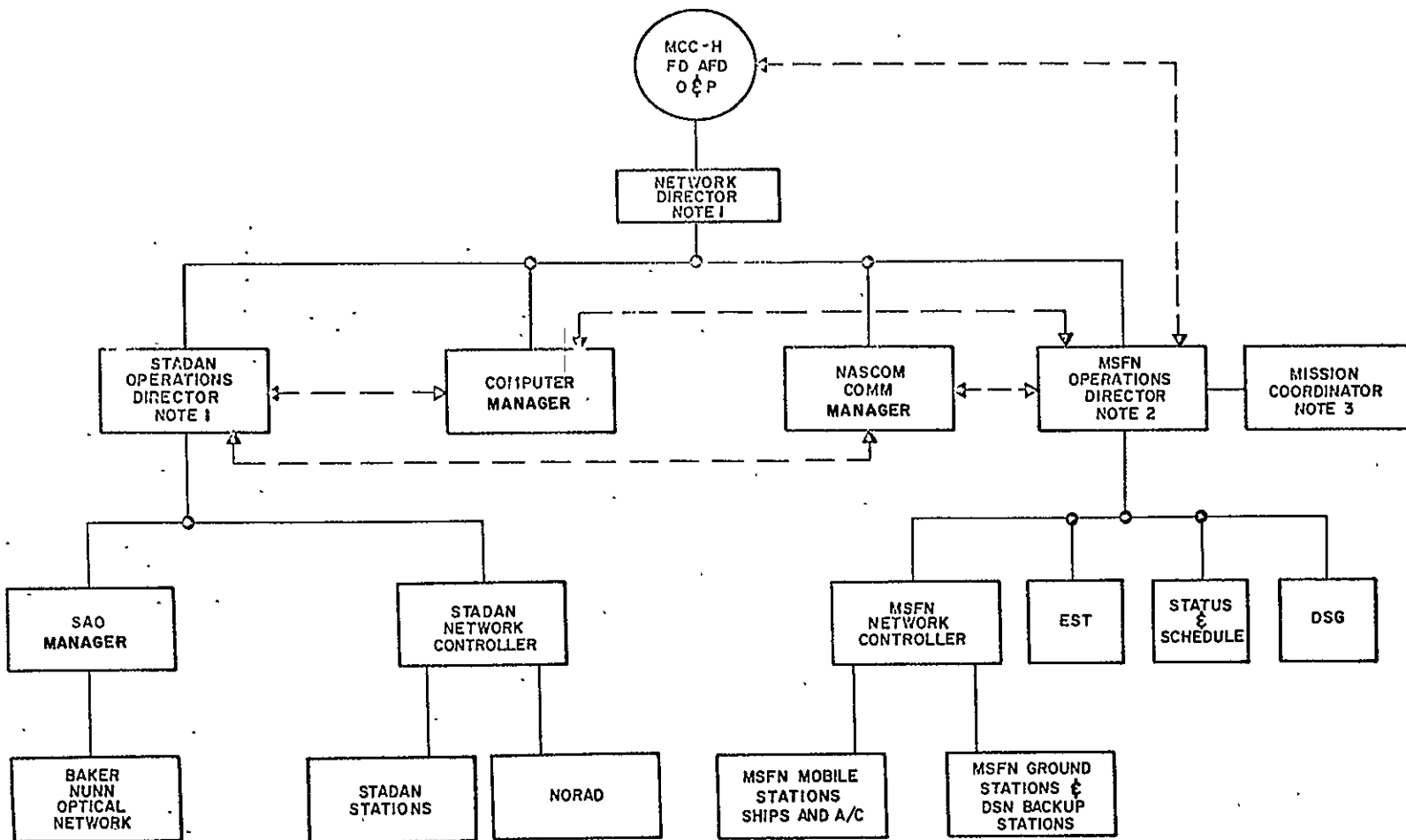


Figure 36-24 Hour MSF Network Direction and Control



NOTES:  
 1. ONE INDIVIDUAL FOR MISSION INITIALIZATION ONLY  
 2. THREE INDIVIDUALS (1 PER SHIFT) ON A 24 HOUR BASIS  
 3. APPROX. SIX INDIVIDUALS (1 FOR EACH MISSION)

Figure 37-AES Initialization Mission

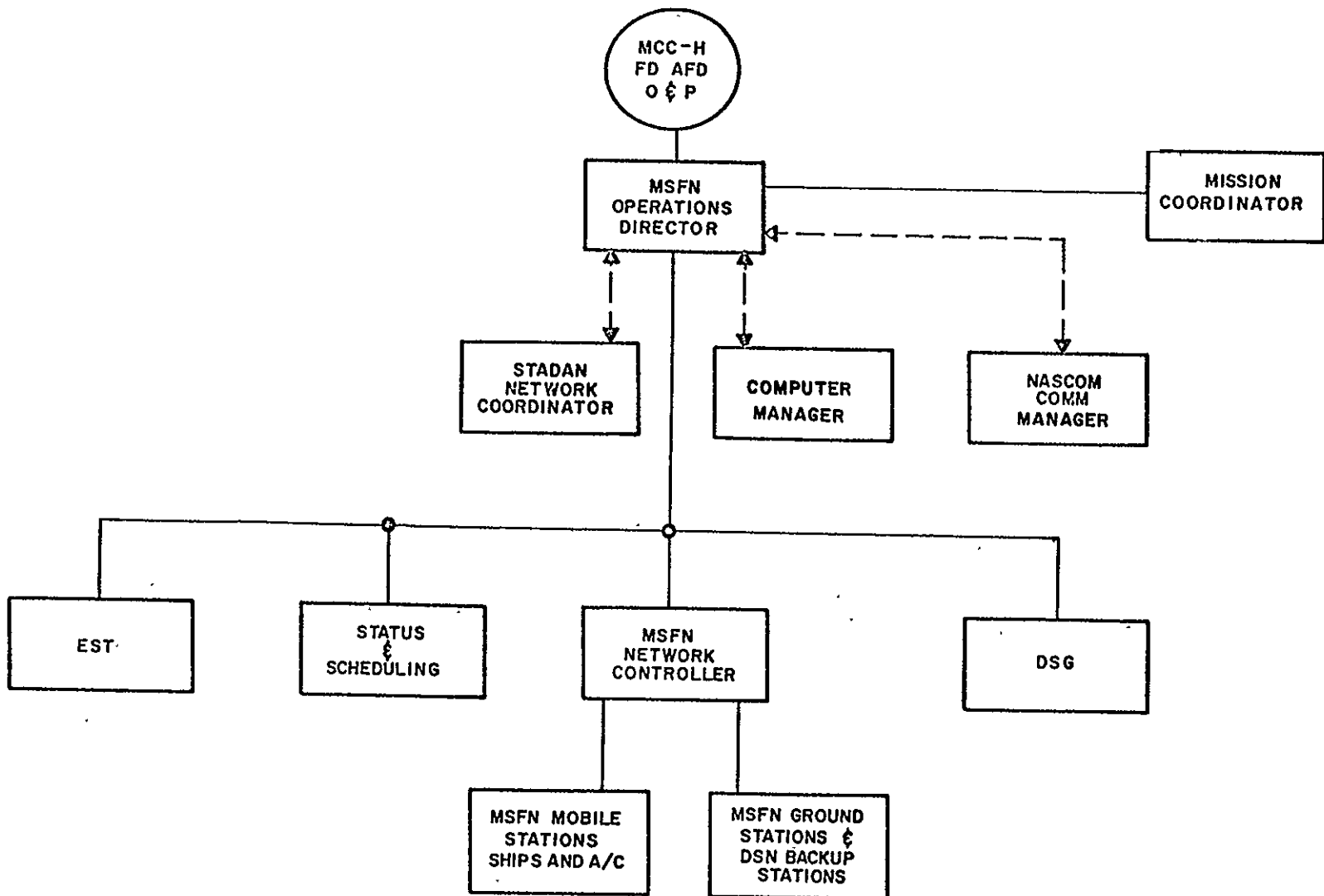


Figure 38—AES Sustained Mission Support

a. Mission Initialization Period

(1) Figure 37 shows the organizational chart for integrated network control during the mission initiation period. The Network Director is responsible for all overall operations pertinent to network activity and for assuring coordination between the various supporting elements such as communications and computing at GSFC. He is responsive to the Flight Director or his designated representative in all mission-oriented matters.

(2) The STADAN Operations Director is responsible for directing the efforts of the STADAN support personnel and for assuring coordination of efforts with the NORAD and the SAO.

(3) The MSFN Operations Director is responsible for directing the relative efforts of the MSFN and all support personnel. He is responsive to the Network Director and to the Flight Director or his designated representative. He is assisted by a Mission Monitor (Project Coordinator) whose task is to follow one complete mission (or project) from the initial requirements stage through completion of the mission. Since the Operations Director is supporting several missions concurrently, he will be provided with assistance and advice by the specialist for each unique mission or program. The Mission Monitor (Project Coordinator) is concerned with receiving mission requirements, assuring data handling compliance and assisting the Operations Director in implementing the requirements.

(4) Supporting Personnel are divided into four groups whose activities are coordinated and supervised by the MSFN Operations Director.

(a) An Engineering Support Team (EST) will provide technical advice to the Flight Director, MSFN Operations Director, Network Controllers, and stations as required. The team will consist of equipment specialists who monitor the network equipment performance and provide real time engineering analysis to maintain efficient equipment operation.

(b) A Scheduling and Status Group will continuously monitor the status of equipment of all MSFN facilities, and bring to the attention of instrumentation and/or logistics personnel those items requiring immediate action. This group will schedule all network and associated activities on a 24 hour basis, and will revise the schedule as the need arises.

(c) A Documentation Group will maintain a library of all current mission documentation and will revise the documents in real time. This group will also maintain the responsibility for answering inquiries about network operational support. The group will coordinate with the Operation and Procedures Group at MCC-H, and with the EST in all cases where changes might affect mission support. This group will maintain up-to-the-minute documentation for every mission being supported.

(d) A Network Control Group will supply "Network Controllers" for 24 hour operations. This group of Network Controllers will be the specialists on "Network Procedures." They will communicate with the M&O Supervisors at each station, keep the sites updated on countdown information, mission progress, etc., and coordinate test programs which may be running concurrently with missions. Real time activities, such as radar handover and command handover will be conducted by this group.

b. Sustained Mission Support

(1) Figure 38 shows the organization for sustained mission support. This organization will permit the network to be responsive to the Flight Directors of all manned missions on a 24 hour a day basis, while, at the same time, permitting each station enough down-time to perform sufficient routine maintenance to prevent catastrophic equipment failures. Because of the complexity of this task, this organization must have considerable authority and leeway in making station tracking assignments. The organization must, for instance, have the authority to decide which one of two, three, or four stations able to see a vehicle at the same time should be assigned tracking responsibility for that vehicle. It would operate under a set of general guidelines and reference decisions to higher authority only when special situations occur.

(2) The MSFN Operations Director is responsible for directing the efforts of the MSFN and all support personnel. In this configuration he is responsive to the Flight Director or his designated representative. He is assisted by a Mission Coordinator who carries on the task as implemented in the initialization configuration.

(3) Supporting Personnel

Engineering Support Team, Scheduling and Status Group, Documentation Group, and Network Control Group have to perform in this configuration in the same manner as in the initialization configuration.

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## IX. GLOSSARY

AA	Acquisition Aid
ABRA	Canberra, Australia
ACRO	Carnarvon, Australia
AES	Apollo Extension System
AESWG	Apollo Extension System Working Group at GSFC
AF	Air Force (also audio frequency)
AFETR	Air Force Eastern Test Range
A/G	Air to Ground or Ground to Air (usually referenced to voice transmission)
ALDS	Apollo Launch Data System
AM	Amplitude Modulation
AMR	Atlantic Missile Range (has been renamed see AFETR)
ANT	Antigua ( <u>sometimes</u> Antenna)
ASC	Ascension Island
ASROSS	Apollo Space Radiation Operational Support Section
AZUSA	Automatic, High Precision, Real Time Trajectory Measuring System
BDA	Bermuda
BCD	Binary Coded Decimal
BRA	Canberra
CADFISS	Computation and Data Flow Integrated Sub-System

CAL	Pt. Arguello, California
C-BAND	3900-6200 Mc
CDU	Computer Display Unit
CM	Command Module (part of Apollo Spacecraft)
CMD	Command
CNV	Cape Kennedy
COIN	Coincidence
COINCIDENCE TIMER	GMT Time of Coincidence
CRO	Carnarvon
CSM	Command and Service Module (part of Apollo Spacecraft)
CSQ	Coastal Sentry Quebec (ship)
CTN	Canton Island
CYI	Canary Islands
DAF	Data Acquisition Facility
DCS	Digital Command System
DCSDC	Digital Command System, Distribution Console
DDD	Data Distribution and Display
DET	Detector
DOD	Department of Defense
DRED	Data Router and Error Detector
DRUL	Down Range Up Link

DSDP	Data System Development Plan
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
EDS	Emergency Detection System (occasionally Electronic Data System)
EGL	Eglin Air Force Base
E/T	Engineering and Training Facility (Wallops)
EVA	Extra Vehicular Astronaut (Activity)
FC	Flight Control
FDO	Flight Directors Operations
FDX	Full-Duplex (Transmission Capability in Both Directions Simultaneously)
FM	Frequency Modulation
FMAP	Flight Mission Assignment Plan
FPS	Fixed Search Radar
FSK	Frequency Shift Keyed
GAEC	Grumman Aircraft Engineering Corporation
GBDA	Bermuda
GBI	Grand Bahama Island
GDAP	Ground Data Acquisition Plan
GFE	Government Furnished Equipment
GGYM	Guaymas, Mexico
GISP	Ground Instrumentation Support Plan

GLD	Goldstone, California
GLGE	College Station, Fairbanks, Alaska
GLOTRAC	Global Tracking System (AF)
GMT	Greenwich Mean Time
G&N	Guidance and Navigation
GODS	Goldstone, California
GR&RR	Goddard Range and Range Rate System
GSFC	Goddard Space Flight Center
GTEX	Corpus Christi, Texas
GTI	Grand Turk Island
GUGB	Grand Bahama
GUM	Guam
GUMI	Merritt Island, Kennedy Space Center
GUNT	Antigua Island—
GUSC	Ascension Island
GYM	Guaymas, Mexico
HAW	Hawaii
HF	High Frequency (3 - 30 MC)
HOR	Horizon
HSD	High Speed Data
IF	Intermediate frequency

IMCC	Integrated Mission Control Center (has been renamed; See MSCC)
INOP	Integrated Network Operations Plan
I/O	Input/Output
IRIG	Inter-Range Instrumentation Group
ISPO	Instrumentation Ships Project Office
IU	Instrument Unit (Part of Apollo Spacecraft)
JPL	Jet Propulsion Laboratory
KNO	Kano, Nigeria
KSC	Kennedy Space Center
LCC	Launch Control Center
LCYI	Canary Island
LEM	Lunar Excursion Module (Part of Apollo Spacecraft)
LMAD	Madrid, Spain
LO	Local Oscillator
LOR	Lunar Orbit Rendezvous
LOS	Loss of Signal
LS	Lunar Survey
LSD	Low Speed Data
L/V	Launch Vehicle
MAD	Madrid, Spain
MAN	Manual
MCC-K	Mission Control Center (Cape Kennedy, Fla.)

MCC-H	Mission Control Center (Houston, Tex.)
MILA	Merritt Island Launch Area
M&O	Maintenance and Operation
MOCR	Mission Operations Control Room
MSC	Manned Spacecraft Center
MSCC	Manned Spaceflight Control Center (Houston, Tex.)
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
MUC	Muchea, Australia
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communication Network
NRZ	Non-Return to Zero
NSP	Network Support Plan
OD	Operations Directive Document
ODOP	Offset Doppler Velocity and Position
OMSF	Office of Manned Space Flight
OSSA	Office of Space Sciences & Applications
OTDA	Office of Tracking and Data Acquisition
P/A	Power Amplifier
PAM	Pulse Amplitude Modulation
PCM	Pulse Code Modulation
PDM	Pulse Duration Modulation

PDP	Project Development Plan
PGWN	Guam
PHAW	Kuaia, Hawaii
PM	Phase Modulation
PMP	Premodulation Processor
PMR	Pacific Missile Range (has been renamed, see AFWTR)
PRE	Pretoria, South Africa
PRF	Pulse Repetition Frequency
PRN	Psuedo Random Noise
PSDP	Project Support Development Plan
PSK	Phase Shift Keyed
PSRD	Program Support Requirements Document
RCS	Reaction Control System
RF	Radio Frequency
RFI	Radio Frequency Interference
RKV	Rose Knot Victory (ship)
S-BAND	1550-5200 Mc
S/C	Spacecraft
SCAMA	Station Conferencing and Monitoring Arrangement
SCO	Sub-Carrier Oscillator
S-IVB	Last Stage of Saturn V Launch Vehicle
SLA	Spacecraft LEM Adapter

SM	Service Module (part of Apollo Spacecraft)
S/N	Signal/Noise Ratio
SSB	Single Side Band
STADAN	Satellite Tracking and Data Acquisition Network
TEX	Corpus Christi, Texas
TLM	Telemetry
TR	Time to Retrofire
TTY	Teletype
TV	Television
UDL	Up-Data Link
UHF	Ultra High Frequency (300 Mc - 3 Gc)
USB	Unified S-Band
USBS	Unified S-Band System
VERLORT	Very Long Range Tracking
VHF	Very High Frequency (30 - 300 Mc)
VLf	Very Low Frequency
VOX	Voice Operated Transmission
WBD	Wide Band Data
WHS	White Sands, New Mexico
WLP	Wallops Island
WSMR	White Sands Missile Range

## X. NOMENCLATURE

$a$	Semi-major axis of the osculating conic
$e$	Eccentricity of the osculating conic
$H$	Height of the vehicle above the earth
$i$	Inclination of the instantaneous orbital plane to the earth's equatorial plane, measured counterclockwise from due East on the equatorial plane to the orbital plane at the ascending node
$M$	Mean anomaly of the vehicle in the osculating conic
$T$	Epoch Time—date of given parameters, universal time
$V$	Magnitude of the velocity vector (earth-centered, inertial)
$X, Y, Z$	Coordinates of vehicle in earth-centered inertial system defined as follows:  + $X$ direction from earth's center toward vernal equinox  + $Y$ direction such as to form a right-handed system with the $Y$ and $Z$ axes  + $Z$ direction from earth's center north along the polar axis
$X, Y, Z$	components of the velocity vector in the above-described system
$\alpha$	Azimuth of the velocity vector, spherical angle measured clockwise from due north
$\lambda$	Flight path angle measured clockwise from the normal to the radius vector to the vehicle velocity when viewing the orbital plane anti-parallel to the angular momentum vector
$\epsilon$	Elevation angle of the vehicle above the local horizon
$\Omega$	Right ascension of the ascending node of the osculating conic
$\omega$	Argument of perigee of the osculating conic, measured in the direction of vehicle motion from the instantaneous ascending node